Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

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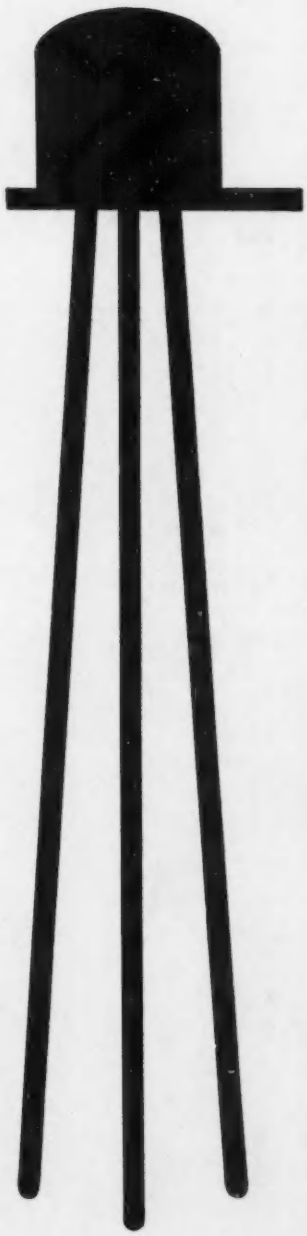
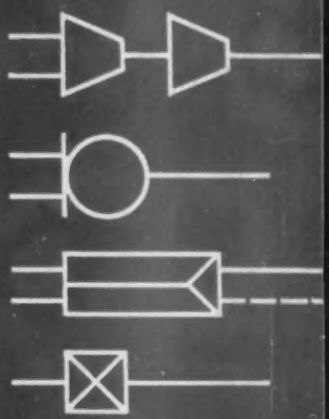
MARCH 1961



A CONTROL ENGINEERING SPECIAL REPORT

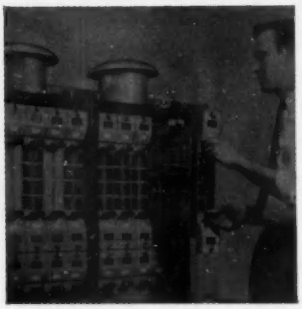
Transistor Switches for Industrial Service



PLUS—Control Engineer's Guide to IRE Sessions

LIBRASCOPE COMPUTER FACILITIES

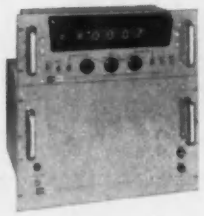
Shown below is a composite view of Librascope's facilities where a variety of computer systems are currently in different stages of design and production. Some are strategically involved with national defense...others deal with business and industrial process control. Each is uniquely designed to answer a particular need. The success of these systems illustrates the value of Librascope's engineering philosophy: A decentralized organization of specialized project teams responsible for assignments from concept to delivery...and backed up by excellent research, service, and production facilities. For your computer requirements, call on the company whose breadth of diversification in computer technology is unsurpassed. ■ Librascope Division, General Precision, Inc., 808 Western Avenue, Glendale, Calif. For career opportunities write to John Schmidt, Engineering Employment. ■



computers that pace man's expanding mind

CIRCLE 233 ON READER SERVICE CARD

NOW! standards lab precision... with military reliability!



Rugged new KIN TEL programmable Digital Voltmeter designed to MIL-E-4158A ...measures AC and DC from 0.001 to 999.9 volts with an accuracy of 0.01% ±1 digit DC, 0.1% AC

USED IN MAJOR MISSILE PROGRAMS. Extensively tested and proved in the field in missile checkout systems, the Model 412 Digital Voltmeter is designed to meet the stringent environmental requirements of MIL-E-4158A for operational ground support equipment. These units have established an unprecedented record of reliability and accuracy in daily service for ICBM testing.

DESIGNED FOR AUTOMATIC SYSTEMS. All major control functions can be remotely programmed... the readout unit remotely mounted in as little as 3½" of rack space. Two isolated input channels are provided, with AC and DC measurement mode and automatic or manual ranging independent for each channel. Digital recorder drive capability is built in.

THE ONLY DIFFERENTIAL DIGITAL VOLTMETER. Completely isolated, guarded inputs eliminate ground loop problems, reject common-mode hum and noise, allow stable, accurate AC or DC measurement at differing ground potentials—regardless of whether printer or other output equipment is grounded or floating.

TEST MISSILES OR TRANSISTORS. If you can't afford down time at the wrong time, if you must have continuous, reliable operation even under adverse environmental conditions, if you need automatic system capability, high accuracy, versatility, then this new KIN TEL Digital Voltmeter meets *your* requirements. Write for technical literature or demonstration. Representatives in all major cities.

BRIEF TECHNICAL SPECIFICATIONS

DC RANGE:
±0.001 to ±999.9 volts in 3 automatic or manual ranges, automatic polarity.

AC RANGE:
0.001 to 999.9 volts, in 3 automatic or manual ranges, 60 to 1000 cps.

ACCURACY:
0.1% of FS for AC, 0.01% ±1 digit of reading for DC.

INPUT IMPEDANCE:
10 megohms for DC, 1 megohm and 200 $\mu\mu$f for AC.

COMMON MODE REJECTION:
86 db minimum for 60 cps common-mode signals.

OPERATIONAL FEATURES:
All controls remotely programmable, built-in digital recorder drive, two isolated input channels with range control and AC or DC mode independent for each channel.

5725 Kearny Villa Road,
San Diego 11, California
Phone: BRowning 7-6700

KIN TEL
A DIVISION OF
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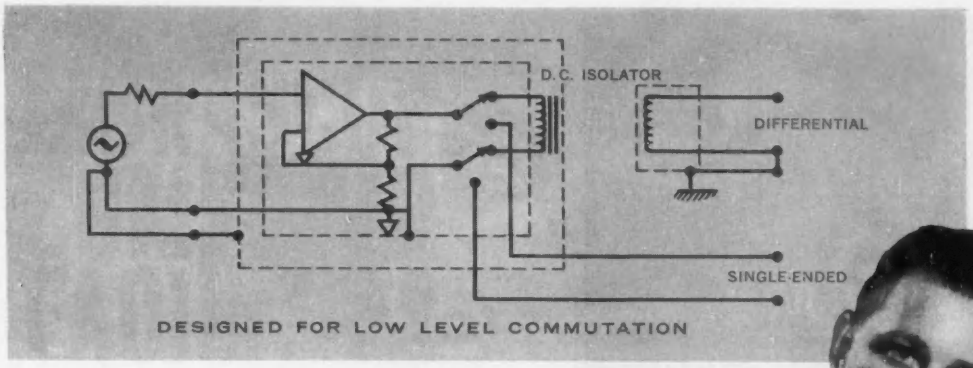
ELECTRONICS, INC.

CIRCLE 1 ON READER SERVICE CARD 1



Announcing the

TDA 875 SOLID STATE

Differential and Single-Ended AMPLIFIER*

- *Recovery from 500% overload in 300 microseconds.*
- *Output voltage clamped at ±13 volts, can't burn out delicate recording equipment.*
- *Completely isolated, 3000 megohm leakage path to ground.*

Built to meet the needs of the engineer designing low-level multiplexing systems, Epsco-West's new TDA 875 Differential Amplifier features high reliability, high gain, wide band-width, negligible drift, high ac/dc common mode rejection, low noise, fast rise time, fast recovery time, integral power supply, and high input impedance. No other amplifier combines all these design parameters to such a useful degree.

DESCRIPTION

The Model TDA 875 contains an integral power supply which operates from a 117-volt, 60-400 cps line, requiring only 15 watts of power. Chopper drive circuits are included with each amplifier.

Two modes of operation are available: differential and single-ended (potentiometric); selection is made by means of a front panel control. Five fixed gains are also chosen by a front panel switch.

In its differential mode, the amplifier provides ±10 volts at 10 milliamperes as its full scale output; in its single-ended mode, full scale output is ±10 volts at 50 milliamperes. High input impedance ensures that all transducer voltage will appear at the amplifier input terminals. Changes in transducer or line resistance will have little consequence.

The Model TDA 875 Amplifier may be mounted in the Model TDA 870A Carrying Case for easy portability, or in the Model TDA 870 Rack Adapter which holds 5 amplifiers in a standard 19-inch relay rack.

**One of six new E-W amplifiers now available to meet your low-level instrumentation needs.*

CRITICAL SPECIFICATIONS
(Differential Mode)

VOLTAGE GAIN
Fixed steps of 1000, 500, 200, 100, 50. Lower gains optional.

LINEARITY
±0.05% of full scale (20 volts at dc)

INPUT IMPEDANCE
Greater than 100 megohms shunted by 0.002 microfarad.

COMMON MODE LEVEL
±300 volts dc, 117 volts rms ac

TRANSIENT COMMON MODE RECOVERY
300 volt step of common mode voltage does not cause overload.

DRIFT – 40 HOURS
±2 microvolts referred to the input, plus ±0.02% of full scale at 25°C.

DRIFT – 6 MONTHS
±4 microvolts referred to the input, plus ±0.02% of full scale at 25°C.

NOISE REFERRED TO THE INPUT
Less than 2 microvolts peak-to-peak (99% confidence) from dc to 20 cps. Less than 5 microvolts rms from dc to 5 kc for source resistances of 1000 ohms or less.

SETTLING TIME
300 microseconds to within 1% of final value all ranges.

OVERLOAD RECOVERY TIME
300 microseconds or less to within 1% of final value from 500% overload.

SHORT CIRCUIT PROTECTION
Sustained output short circuit will not damage amplifier.

Ask your nearby Epsco-West engineering representative to demonstrate these new amplifiers. For complete technical information, write for Brochure No. 875. Please address Dept. 21.

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Control ENGINEERING

MARCH 1961

VOL. 8 NO. 3

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

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solid state
DIGITAL PRINTER

the 400 CT -

The most versatile digital printer ever made

SPECIFICATIONS

Printout capacity	6 digits standard.
Accuracy	determined by basic counting instrument.
Display time	0.2 seconds minimum, maximum controlled by the counter.
Weight	60 lbs.
Power requirements	115 volts ±10%, 50-60 cps 25 watts
Dimensions	17" W x 8½" H x 16½" D. (Rack mounting available as option D.)
Warranty	One year on electronics; 1.5 million lines @ 4 lines per second on matrix; 10 million lines @ 4 lines per second on printer assembly, or 1 year, whichever occurs first.
Price	$1350.00. Add $10.00 for rack mount.

* 4 lines per second printout * Takes 1-2-2-4 or 1-2-4-8 four line code * No stepping switches * Operates from only 3 volt input * Parallel entry * Special options available including 10 line and analog output * 6 digit printout, up to 12 digits on special order * Rugged unitized construction * Completely compatible with CMC's new solid state frequency-period counters, and other types of transistorized counting equipment.

For a demonstration of this remarkable new printer and complete technical information, call your nearby CMC engineering representative or write to us direct. Please address Dept. 21.

CMC

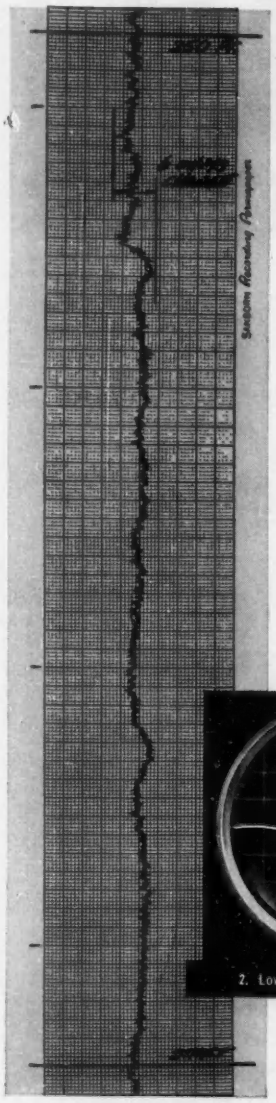
Computer-Measurements Company *A Division of Pacific Industries, Inc.*

12970 Bradley Avenue • Sylmar, California

Phone: EMpire 7-2161

20A

How to produce better
POTENTIOMETERS
without increasing costs



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Use Hoskins
Chromel-R
Premium Potentiometer Grade Wire

a new custom-quality nickel-chromium alloy especially developed, processed and controlled to assure you of:

1 Closer independent linearity, with maximum total deviation continuously controlled to within .012% over any 250 feet of wire.

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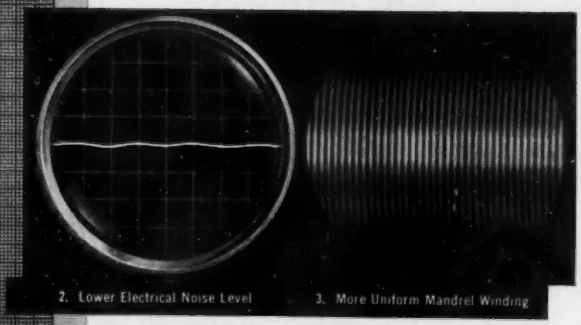
3 Greater efficiency in winding mandrels—with more uniform spacing between turns—due to its superior wire roundness.



2. Lower Electrical Noise Level 3. More Uniform Mandrel Winding

If you make POTENTIOMETERS this wire is right for you!

It's premium in quality but not in price. And sample spools plus complete technical data are available now to potentiometer manufacturers for immediate testing and evaluation. Your request on company letterhead will receive our prompt attention.

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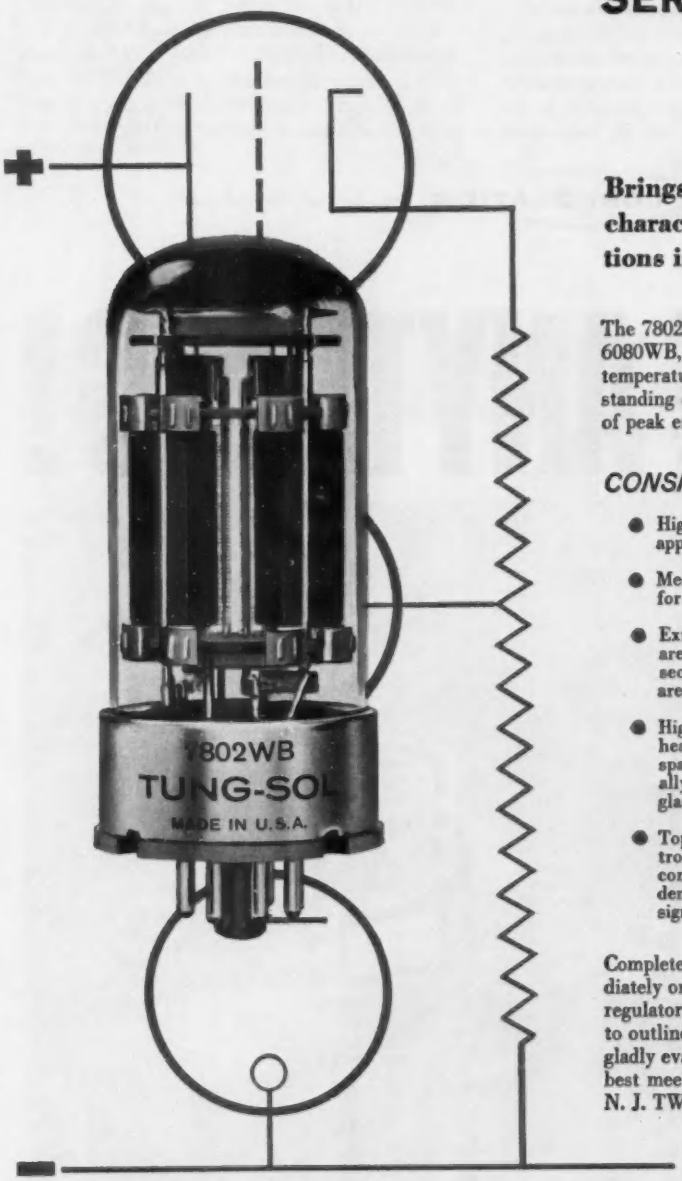
NEW MEDIUM-MU
SERIES REGULATOR TUBE
7802WB



Brings together an optimum combination of characteristics that makes it ideal for applications in tough environmental extremes.

The 7802WB twin-triode, medium MU companion to the popular 6080WB, is the newest in the broad Tung-Sol line of rugged, high temperature, long-life series regulators. It combines many outstanding operational and design features in an optimum package of peak efficiency and dependability.

CONSIDER JUST THESE FEATURES:

- High perveance . . . Makes the 7802WB an excellent choice for applications requiring high plate current at low plate voltage.
- Medium-mu . . . Makes only very small signal voltages necessary for precise 7802WB control.
- Extra-tight tolerances . . . Plate current and transconductance are held to rigid limits to provide greater balance between tube sections. This is of particular significance where many sections are operated in parallel.
- High temperature operation . . . Extensive use of ceramics for heater-cathode insulators, anode standoff insulators and element spacers. The graphite anodes used are warp-free and dimensionally stable regardless of operating temperatures. Non-char, glass-bonded mica material is employed in the tube base.
- Top-performance in environmental extremes . . . Where electronically regulated power supplies must perform under severe conditions of shock vibration and high altitude, the 7802WB demonstrates long, trouble-free life, assured by both tube design and specifications.

Complete technical details on the 7802WB will be furnished immediately on request. A description of the full-line of Tung-Sol series regulator tubes is also readily available. Tung-Sol also invites you to outline your design needs to us. Our application engineers will gladly evaluate your circuit and outline the component which will best meet your requirements. Tung-Sol Electric Inc., Newark 4, N. J. TWX:NK193

TUNG-SOL®

Technical assistance is available through: Atlanta, Ga.; Columbus, Ohio; Culver City, Calif.; Dallas, Texas; Denver, Colo.; Detroit, Mich.; Irvington, N. J.; Melrose Park, Ill.; Newark, N. J.; Philadelphia, Pa.; Seattle, Wash. In Canada: Abbey Electronics, Toronto, Ont.

measure the volume of a pulse beat . . . the weight of a breath . . . the vacuum of outer space
measure gyro rotor unbalance . . . liquid level in a remote tank . . . the thickness of a continuous sheet of hot metal

Convert any variable into a change in capacitance and there's a Delta unit available to measure, record, or control that variable more accurately and more economically than was ever before possible.

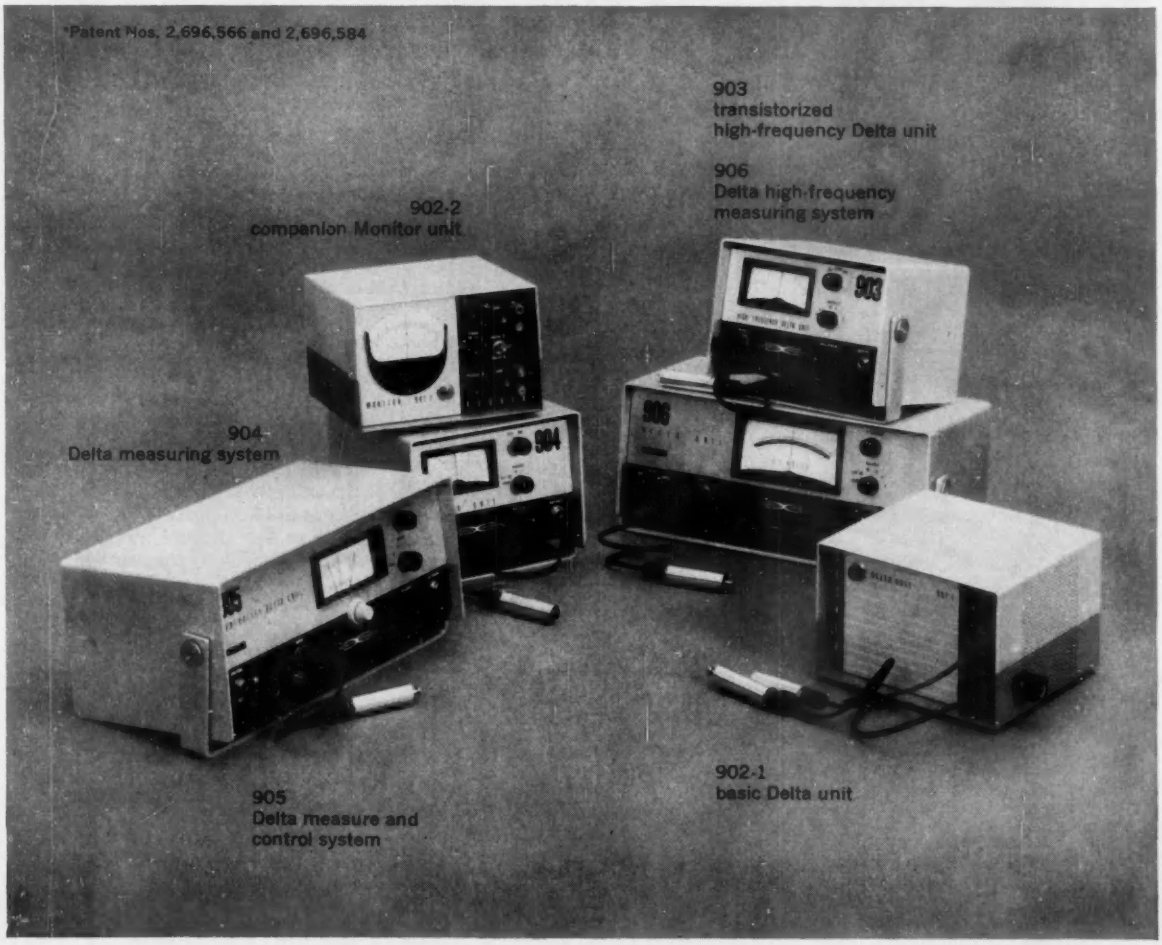
You just plug the Delta unit into a 115 Vac supply and hook up the probes to your simply constructed capacitance sensor. Capacitance changes as slight as 1% generate output voltages as large as 0.2 Vdc, indicating direction as well as magnitude.

Everything you need for measurement in the laboratory, on the bench, or in the field is built right into one or another instrument in the Delta family. All incorporate the proved principle of the Decker T-42 Ionization Transducer*, the most important advance in measurement in decades. All models but 902-1 have internal meters. Or, you can easily bypass the meter and feed results directly into external display, recording, or control equipment.

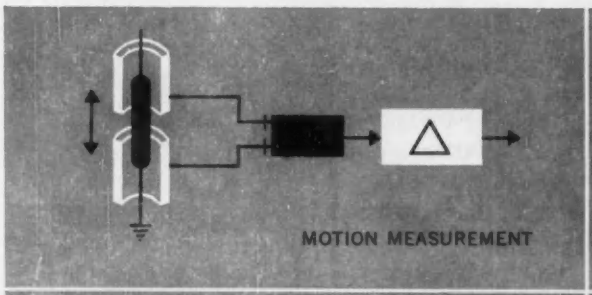
Write for complete details, specifications, and application suggestions in Series 900 Instrument Data Sheets, available without obligation. Or, just let us have your measurement problem, and we'll gladly recommend a practical solution.

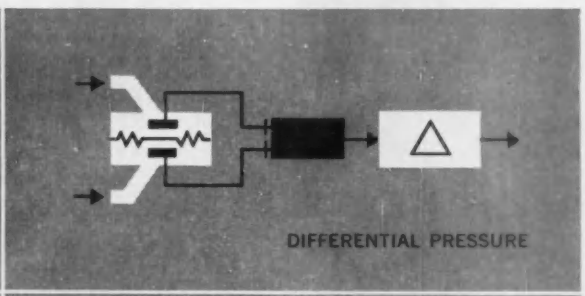
THE DECKER CORPORATION *Bala-Cynwyd, Pennsylvania*

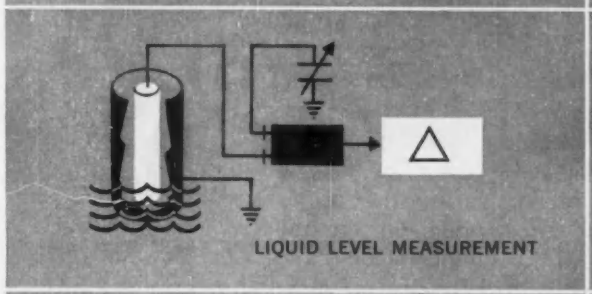
MEASURE ANYTHING!

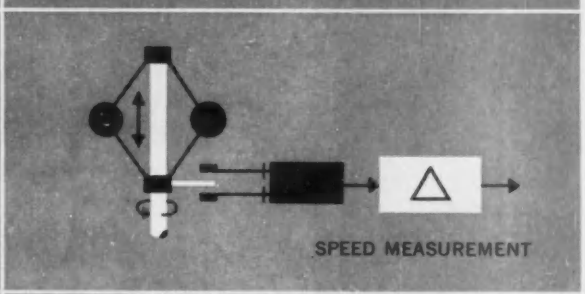


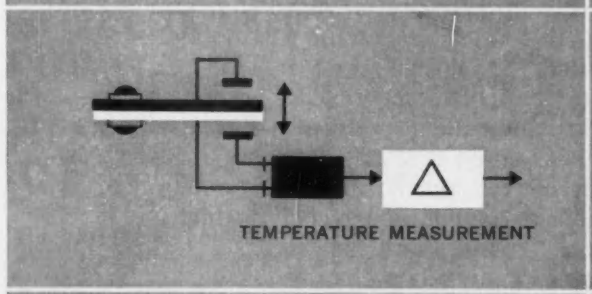
DECKER'S DELTA UNIT makes non-contact capacitance gauging practical and economical for the first time. Compared with conventional capacitance measuring systems, the Delta unit has no complex circuitry, provides excellent long-term stability. The basic Delta unit is little more than a stable RF oscillator which excites the T-42 Ionization Transducer. The transducer output itself is a phase-sensitive differential d.c. voltage analogous to any change in capacitance across the probe terminals. Here are just a few of the uses to which Decker Delta units are daily put in research laboratories, manufacturing plants, defense installations, and hospitals.

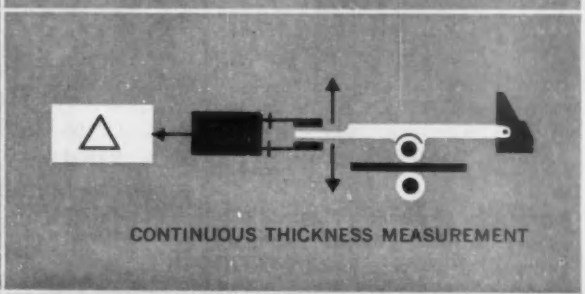


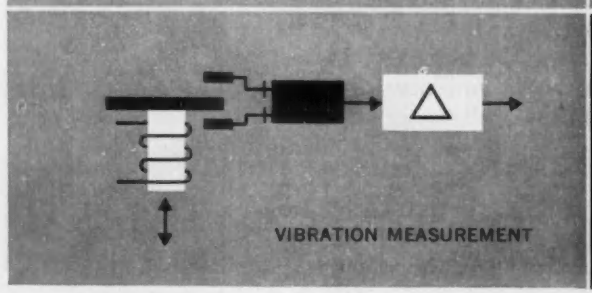








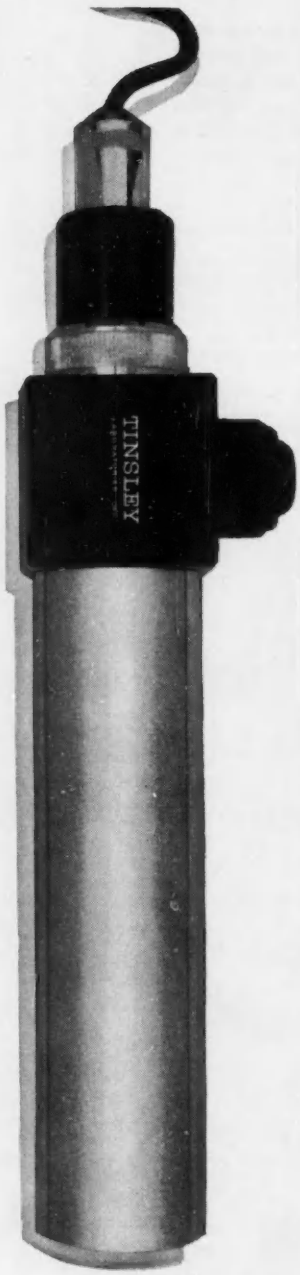




If the instruments discussed here cannot solve your measurement problem, we will gladly bend our efforts toward developing a Delta instrument that will.

THE DECKER CORPORATION

Bala-Cynwyd, Pennsylvania



Why pay for an expensive alignment telescope when a Tinsley Autocollimator may meet your requirements for hundreds of dollars less? The Tinsley Autocollimator is easily capable of reading precise angles to ¼ minute accuracy. 20 power. Interchangeable light source and eyepiece for viewing from end or side. Fits standard fixtures. Economical and dependably accurate. Write for price and information.

TINSLEY
LABORATORIES, INC.
2526 Grove Street · Berkeley 4, California

SHOPTALK

Top editorial position changes hands

Byron K. Ledgerwood

Shoptalk announces with pleasure that Byron K. Ledgerwood has been appointed chief editor of CONTROL ENGINEERING, replacing William E. Vannah, who filled the top editorial job since the magazine's inception in 1954. Bill returns to The Foxboro Co., where he will provide engineering and market guidance for advanced products and systems. After six years of educating other control engineers through these pages, Bill wants to test his ideas in the marketplace. Fortunately, Vannah remains on the staff as a consulting editor, giving the editors and readers alike the benefit of his experience and counsel. To Bill Vannah, our best personal regards.

Chief Editor By Ledgerwood has been associated with CONTROL ENGINEERING since it was a gleam in McGraw-Hill's eye. As top editor, By now has the responsibility for long range editorial planning and coverage. His previous assignments on the magazine include working on the magazine's pilot issue (1953), and then joining as the first full-time editor and serving successively as associate editor and senior associate editor, and for the last four years as managing editor. By pledges to keep this magazine the prime source of information on control technology and applications.

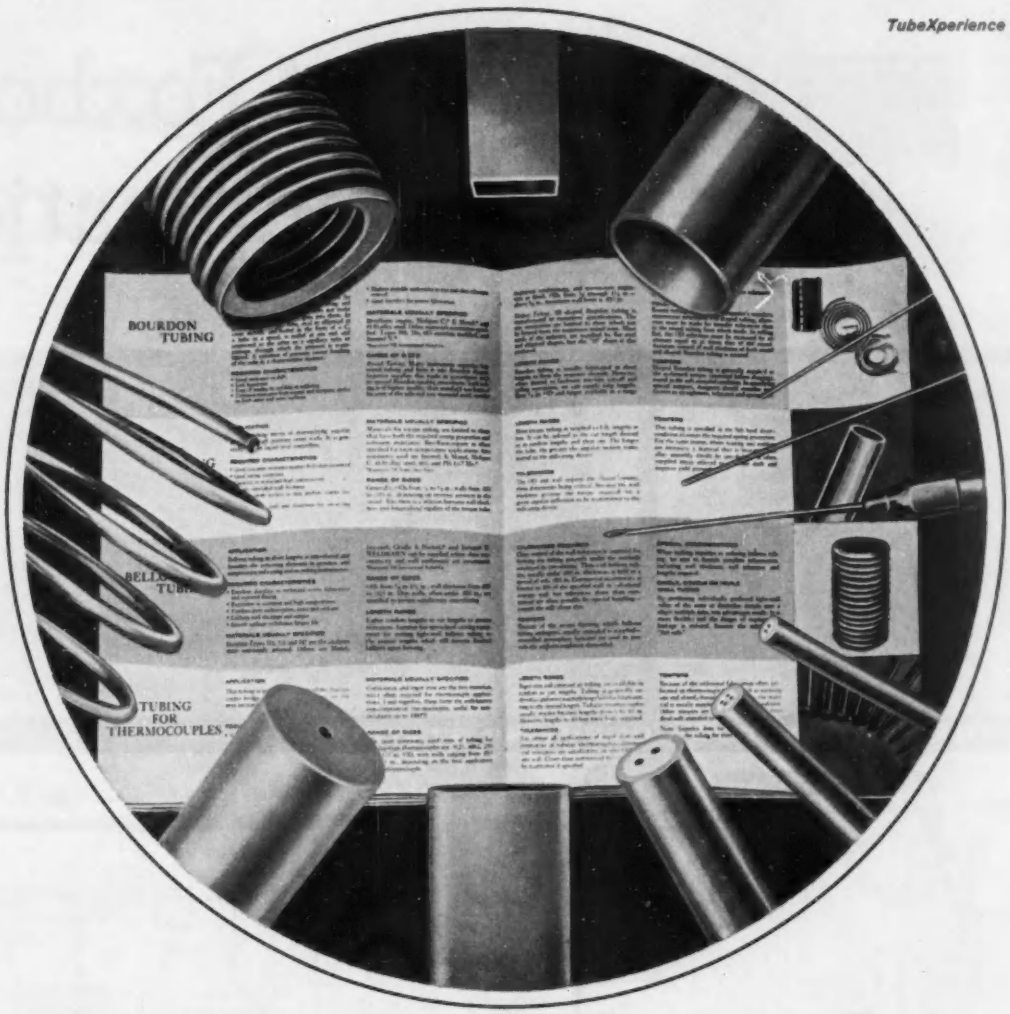
Harry R. Karp

Harry R. Karp has been promoted to managing editor of CONTROL ENGINEERING. Almost a charter member of the editorial staff (he joined us in May 1955), as an associate editor Harry has been responsible for covering control in the raw materials processing industries. But now he must see that we come out on time each month with a well balanced, technically correct, timely, interesting publication. Harry will continue to serve as process control editor.

Lewis H. Young moves up to senior associate editor, a promotion recognizing Lew's fine work in keeping CONTROL ENGINEERING readers abreast of news and new developments. In his challenging position, Lew will direct the news and general interest aspects of the control field, a job that will continue to give the printers gray hair as Young forces his latest scoop into print at press time.

Lewis H. Young

TubeXperience in action



TUBEXPERIENCE PREPARES A NEW INSTRUMENT BULLETIN —GUIDE TO SELECTION AND APPLICATION OF INSTRUMENT TUBING

Superior's long experience in producing small-diameter metal tubing to extremely close tolerances enables it to offer instrument designers and makers a wide variety of materials, sizes, metallurgical competence, and manufacturing skills that save experimentation in the design stage . . . time and cost in production.

"Specialty Tubing for Industrial Instrumentation"—a new bulletin by Superior just off the press—puts into print for the first time comprehensive information that covers all types of Superior tubing for the instrument field. It includes required characteristics, materials usually specified, range of sizes, tolerances, tempers, and special considerations for thermometer-bulb, capillary, Bourdon, bellows, fire detection, linkage, recording-pen and torque tubing; also tubing for thermocouples and gas chromatography.

Send for a copy of this valuable bulletin today. The information covered will greatly help your selection of tubing for all measuring, indicating, recording and control devices. If you have a problem involving tubing, call on us to help you solve it. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

Superior Tube

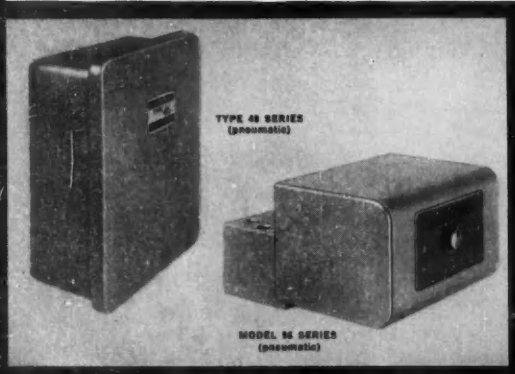
The big name in small tubing

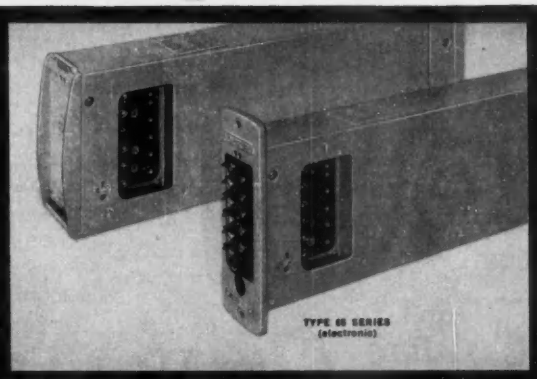
NORRISTOWN, PA.

All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

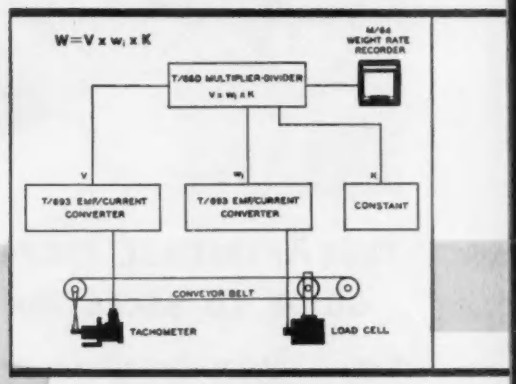
new low-cost Foxboro simplify automation





FOXBORO ANALOG COMPUTING STATIONS

▶ **TYPICAL**



WEIGHT RATE COMPUTATION

Gives operator continuous recording of actual weight of materials being conveyed by belt. For example, T/66D Multiplier-Divider calculates actual weight-rate from load cell and belt speed measurements.

Analog Computing Systems of process mathematics

both pneumatic and electronic units available

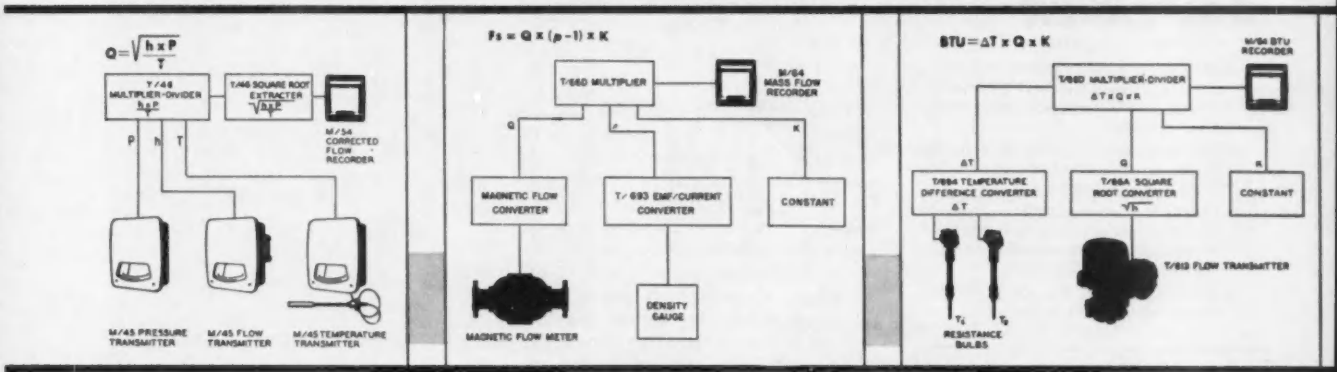
Analog computing systems have been known and used for years. Yet their potential for increasing process efficiency has hardly been scratched.

Just look what they can do! Continuous calculation of all the arithmetic functions: addition, subtraction, multiplication, division, square root extraction — in any combination. And all done automatically by a single packaged system.

And look how it simplifies the operator's job. Instantaneous calculation . . . with records to prove it. No slide rules, no interpolation, no planimeters — and most important — no mistakes.

Because Foxboro Analog Computer Systems are relatively low-cost ($2500-5000 average) you can "spot" them about your plant for maximum efficiency. Or, they can be grouped together at a central location to solve more complicated equations. Pneumatic and electronic systems available.

CALCULATIONS MADE WITH FOXBORO ANALOG COMPUTING SYSTEMS



GAS FLOW COMPUTATION

In common use in the Gas Industry to compensate gas flow readings for changes in line temperature and static pressure. In the pneumatic system shown here, the Foxboro T/46 Multiplier-Divider and the Square Root Extractor allow operator to read corrected flow directly.

MASS FLOW COMPUTATION

Calculates dry weight of a slurry flowing through a pipeline. In this electronic system, flow rate and density measurement are multiplied together with a Foxboro T/66D-1 Multiplier. Operator can then read flow directly in Dry-Tons-Per-Minute.

BTU COMPUTATION

Determines actual amount of heat being introduced to, or removed from, a process. Electronic system shown uses a Foxboro T/66D Multiplier-Divider to produce a signal equal to product of flow and temperature difference. Operator reads directly in Btu's.

WHAT CALCULATIONS WOULD YOU LIKE TO AUTOMATE? ➔

CIRCLE 13 ON READER SERVICE CARD

FOXBORO

REG. U. S. PAT. OFF.

The Foxboro Company, 853 Neponset Ave.
Foxboro, Mass.

I have a process computation I should like to automate. Can a Foxboro Analog Computing System do it for me?

My process is.....

I want to compute.....

.....

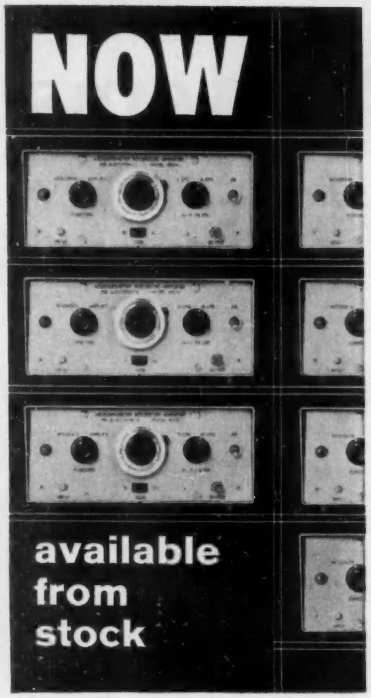
Name.....

Position.....

Company.....

Address.....

City..... **State**.....



MB model N504 INTEGRATOR AMPLIFIER

- Measure acceleration, velocity, or displacement with conventional accelerometers and vibration meters.
- Measure acceleration or velocity from accelerometer input with standard voltmeters.
- Convert accelerometer signals to velocity for automatic control of vibration exciter displacement, velocity or acceleration.
- Eliminate need for cathode follower and power supply.

SPECIFICATIONS

Frequency Response:	**Amplify Position** (5 cps filter) 10–10,000 cps ± 2% 5–10,000 cps ±7% **Integrate Position** (–6 db/octave) 10–2,000 cps ± 5% 5–2,000 cps ±10%
Sensitivity:	**Amplify Position** Maximum gain = 100 **Integrate Position** 1 mv(rms)/"g" peak converted to 96.3 mv (rms)/in./sec.(rms)
Input Impedance:	Greater than 200 megohms
Output Impedance:	Less than 600 ohms

Complete technical details in Bulletin 131. Write...

MB ELECTRONICS

A DIVISION OF TEXTRON ELECTRONICS, INC.
1101 State Street, New Haven 11, Conn.

FEEDBACK

PROBLEM FORUM

A subscriber finds use today of a systems test technique published in 1956. He requests advice on hardware hookups and on analysis of test data. Author Fuchs furnishes both. Ed.

TO THE EDITOR—

In September 1956 your magazine carried an article titled "How to Practice Control Systems Engineering", which recently has been published in book form by CONTROL ENGINEERING.

In this article appeared a section called "Testing Servomechanisms", by Mr. A. M. Fuchs, in which Mr. Fuchs described the techniques used in performing an open-loop frequency response test. He briefly explained two methods to be used in keeping the servo output from drifting from its neutral position while conducting the open-loop test. If possible, I would like to obtain more detailed information on the two methods, such as a sketch showing hardware hookup applied to a linear motion hydraulic servoactuator.

P. S. Coppola
Mechanical Control Engineering
Defense Electronics Div., GE,
Johnson City, N. Y.

P. S. COPPOLA—

Your problem in measuring the frequency response of a linear motion hydraulic servoactuator has the very severe problem of drift. The hydraulic valve which meters oil to the cylinder is not well balanced and will cause the cylinder to go to the end of its stroke before the test data can be taken. Usually high power levels are involved, causing serious mechanical problems in avoiding damage.

There is only one satisfactory approach to your problem and that is to close a position loop around the actuator. Use a position sensor from the actuator and a conventional servoamplifier. It would simplify matters to use a dc positioning system and a continuous feedback potentiometer.

You can then insert your test signal into the servoamplifier and measure the over-all closed-loop response. Having this data and knowing the gain of the servoamplifier, solve for the electrohydraulic actuator response from

$$KG\,(j\omega) = \frac{1/K_a}{\frac{\theta_o}{\theta_i}\,(j\omega) - 1}$$

KG = unknown transfer function
K_a = amplifier gain

$\frac{\theta_o}{\theta_i}\,(j\omega)$ = measured closed-loop response

To simplify the calculation, plot into a Nichols chart on the closed-loop coordinates, and read out on the open-loop coordinates. The accuracy of the measurement and calculation is greatly enhanced if you use a noise rejecting measuring technique.

If the position control loop contains frequency sensitive elements whose response you do not know and that you wish to eliminate from measurement, proceed as follows:

Measure the frequency responses (simultaneously) from position output to test input and from hydraulic actuator input to test input. The ratio of these two responses is the desired transfer function

$$\frac{\theta_o}{\theta_i} = \frac{K_1G_1K_2G_2}{1 + K_1G_1K_2G_2}$$

where K_1G_1 = all other frequency dependent items
K_2G_2 = unknown transfer function
θ_o = output (over-all)
θ_i = input

$$\frac{\theta'_o}{\theta_i} = \frac{K_1G_1}{1 + K_1G_1K_2G_2}$$

where θ'_o = input to item whose transfer function is being measured

$$\frac{\theta_o}{\theta'_o} = \frac{\theta_o/\theta_i}{\theta'_o/\theta_i} = K_2G_2$$

Again, noise rejection in the measuring equipment helps in getting accurate results.

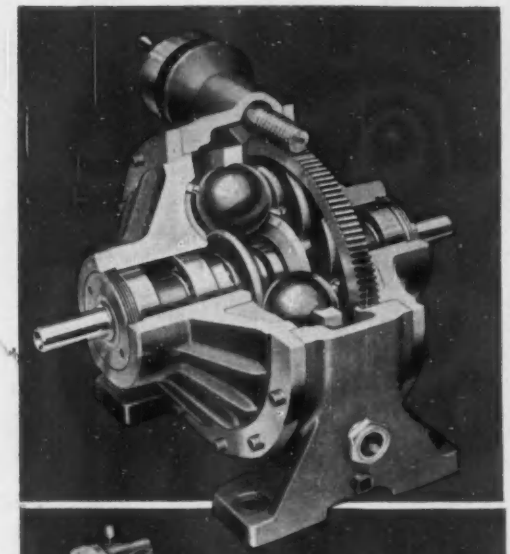
A. M. Fuchs
Boonshaft and Fuchs
Hatboro, Pa.

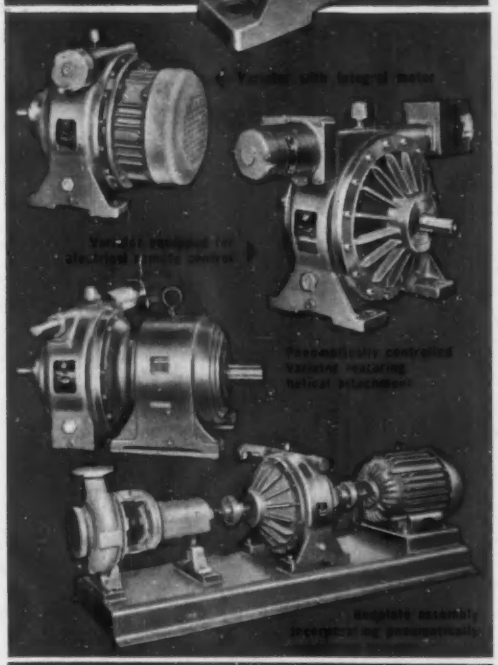
Unintended confusion

TO THE EDITOR—

On pages 128 and 132 of your February issue, in my article on digital data transmission, the main captions on Tables I and III were switched. Table I shows data communication equipment for use on leased or private lines (although the subtitle "subject in each case to approval of the common carrier, if any" is correctly associated with Table I), while Table III on page 132 shows data communication equipment for use on toll telephone circuits.

Robert F. Shaw
Digitronics Corp.





for accurate, dependable, infinitely variable speed control, specify...

CLEVELAND SPEED VARIATOR

Cleveland Speed Variators are simple in operation . . . built for long life. Eighteen models—including a new motorized unit—range from fractional to 16 hp at 1750 input RPM. They all accurately provide dependable, infinitely variable speed control over a full 9:1 range—from ⅓ to 3 times input speed. Instant smooth change of output speed can be adjusted by either manual, automatic or remote control. Precise adjustments are always made with accurate adherence to settings.

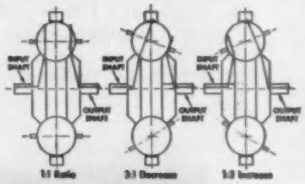
Exclusive Variator advantages:

- An extremely compact unit with input and output shafts in line and rotating in the same direction.
- Almost any input speed up to 1800 RPM can be used—either clockwise or counterclockwise rotation.
- Rated for constant horsepower output over a 9:1 or 6:1 range; or for constant output torque over a 6:1 range.
- Speeds infinitely variable over entire range of adjustment.
- No slippage—positive torque response mechanism adjusts in direct proportion to the loads encountered.
- Long life and minimum maintenance due to absence of belts or complicated linkages.
- Ample bearing support for overhung pulleys on both input and output shafts.

Write today for free Bulletins and Data Sheets shown at left. They contain detailed description, photographs, sectional drawings, rating tables and specifications for the versatile Variator.

Cleveland Worm & Gear Division
Eaton Manufacturing Company
3260 East 80th Street • Cleveland 4, Ohio

Power is transmitted from input shaft to output shaft — rotating in the same direction — through alloy steel driving balls which are in pressure contact with the drive discs. Relative shaft speeds are adjusted by changing position of axles on which the balls rotate.



CLEVELAND SPEED VARIATOR

The versatile transistor servo amplifier by DIEHL

Designed for operation with any DIEHL 1, 5 or 10 watt servomotor at 60 and 400 cycle carrier frequencies, this new series of Transistor Servo Amplifiers is also capable of driving any DIEHL size 11 or 15 servomotors, or equivalent.

Superior electrical performance is typified by near-perfect linearity over a wide range of input voltage and by the absence of measurable phase shift over a 20 cps. passband.

The use of advanced packaging techniques in 2 inch diameter modules produces continuous power outputs of 6 watts in a 1⅞ inch long can or 35 watts in a 3¼ inch long can. Units are *not potted*, for accessibility and ease of maintenance; air-tight cases are filled with inert aluminum oxide particles for maximum heat transfer.

Also available is DIEHL TP 3-100 solid state power supply which accommodates either 6 or 35 watt units by means of direct plug-in.

Please write for additional information. 4178

SEE US AT IRE SHOW
BOOTH 1913-15

SPECIFICATIONS

Cat. No.	TA006-OA-100
Output	Continuous; 10 watts, max. (unmounted in free air at 25 c ambient, no heat fins) 4 watts, max. (mounted on 12" x 12" x ⅛" aluminum plate, at 71 c ambient, with ¼" heat fins)
Gain	1000 volts/volt, nominal
Input Imp.	30K minimum
Phase Shift	a) No measurable phase shift in 20 cps passband for 60 cps carrier b) Less than 10° phase shift in 100 cps passband for 400 cps carrier
Noise	.013 volts, input shorted
Power Req.	−28 ± 2 volts DC at .600 amp.; +9 ± 1 volts DC at .015 amp.

Diehl†

†A Trademark of THE DIEHL MANUFACTURING COMPANY

DIEHL MANUFACTURING COMPANY

A SUBSIDIARY OF THE SINGER MANUFACTURING COMPANY

Somerville, New Jersey

FEEDBACK

An added entry

To the Editor—

Mr. R. F. Shaw in his well written and timely article "What's Available for Digital Data Transmission" (February '61) has omitted the Avco Corp. in his list of manufacturers of digital data communications equipment. This oversight was no doubt due to the very recent introduction of the Avco equipment into the commercial market. Avco manufactures a complete line of data coupler equipment which can be applied in teletype, telephone and microwave transmission of data directly into a data processing system.

Donald L. Segel
Data Handling Dept.
Electronics and Ordnance Div.
Avco Corp.

Information, please—Symposium

To the Editor—

In your January 1961 issue (Volume 8, p. 23) there is a note on a Temperature Symposium to be held at Columbus, Ohio, March 27-31. Could you tell me where I might receive additional information pertaining to this symposium?

J. W. Redmond
Union Carbide Nuclear Co.
Oak Ridge, Tenn.

The 1961 Temperature Symposium is sponsored by the National Bureau of Standards, the American Institute of Physics, and the ISA. For information contact V. W. Sikora, ISA, 313 Sixth Ave., Pittsburgh 22, Pa. Ed.

An opportunity for instrument makers

To the Editor—

Italian University Institutes are finally starting to recognize the necessity of teaching instrument practice in our schools. They have requested that we supply portable and light instruments with direct reading, or with recording, for use in the field and for the following measurements:

- temperature, from minus 25 deg C to plus 24 deg C
- moisture of soil and snow
- pH of water and snow
- radioactivity of water and snow.

We know that scientists in the U. S. have used instruments of this type. Please inform American manufacturers of our need of the instruments.

Fabrica Apparecchi Scientifici (FAS)
Via F. Korista, 8/10
Milan, Italy

We suggest that interested manufacturers contact FAS directly. Ed.

Introducing General Electric's New Line of

Precision Regulated Transistorized DC Power Supplies

- **Convection cooled to eliminate all moving parts**
- **Unique "Constant Watts" circuit protects series transistors**
- **Standard ratings from 1.5 to 100 V.D.C. up to 20 amps.**

Whatever your application, here's a newly-designed series of precision regulated transistorized DC power supplies—for better electrical performance.

"Constant Watts" circuit protects against overloads, short circuits, misadjustments, line voltage variations.

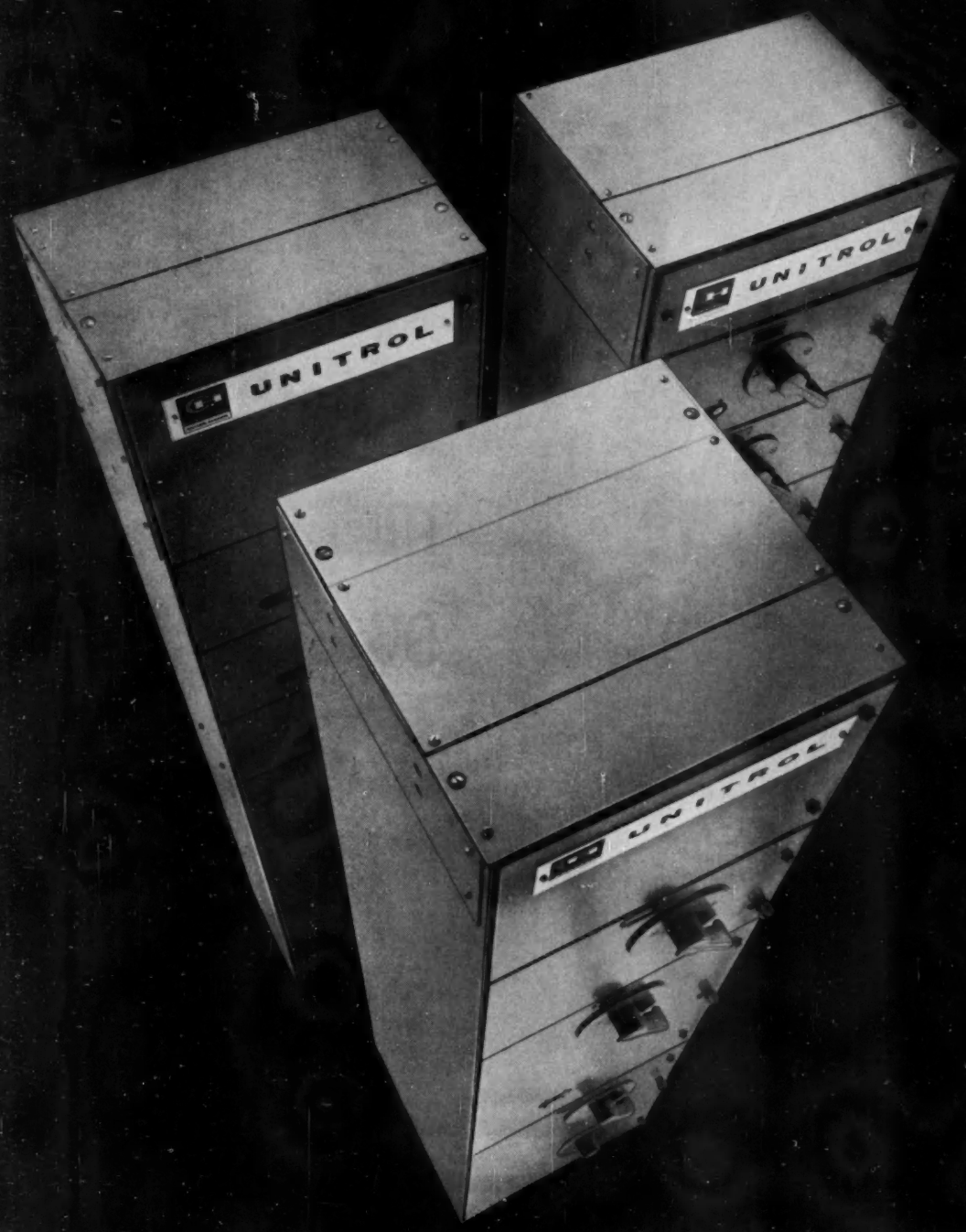
Plug-in printed circuits and 25 percent fewer components increase reliability and reduce maintenance.

Economically priced. Contact your G-E Sales Engineer for information, or write for Bulletin GED-4184, to Section 535-03, General Electric Company, Schenectady, N. Y.

Progress Is Our Most Important Product

GENERAL ELECTRIC

CIRCLE 17 ON READER SERVICE CARD



WHO ELSE BUT CUTLER-HAMMER GIVES YOU ALL THESE FEATURES?

- Quick and safe maintenance
- All front connections
- Tough baked enamel finish
- Completely safe wiring troughs
- Add options . . . no crowding
- Vertical bus silver plated
- Quick latch door fasteners
- Five padlock locations
- 100% interchangeability
- Positive off-power test position
- Modular construction

CONTROL

Now! Cutler-Hammer Unitrol in two new shallow depths!

Get more compactness, more flexibility in motor control centers plus Cutler-Hammer dependability and safety

With Unitrol, you eliminate the high cost of mounting and wiring individual starters, as well as using far less space. Unitrol gives you flexibility, too . . . easy to change starters to fit needs and expand without disturbing other starter units. The two new shallow depths (15″ and 12″) make Unitrol practical even on catwalks or tunnels. Unitrol's modular design lets you put as many as 8 Size 1 starters in a single section and still leave room for many options.

But, probably more important is the safety factor built into Unitrol—safety for the men and machines. For instance, you can *lock* each unit in maintenance position for complete safety. Look at the features at the left for some of the extra values in Unitrol.

What's new at Cutler-Hammer? You can see the new spirit and vitality in a flood of new products and product improvements. Plant capacity has been increased. We've added new engineering talent to increase efficiency. Everywhere you look, you can see that we're ready to help you meet the challenge of the years ahead. Get the inside story from the Cutler-Hammer sales office nearest you.

NEW! FREE! BOOKLET: The "Motor Control Center Handbook" gives you practical facts on selecting the proper control as well as estimating for future needs. Send for Pub. LJ-1 E227 now!

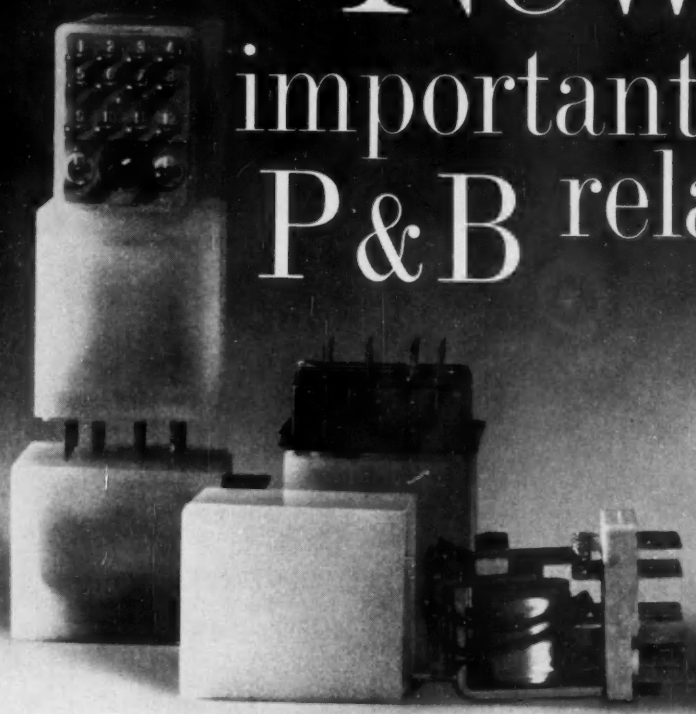
WHAT'S NEW? ASK...

CUTLER-HAMMER

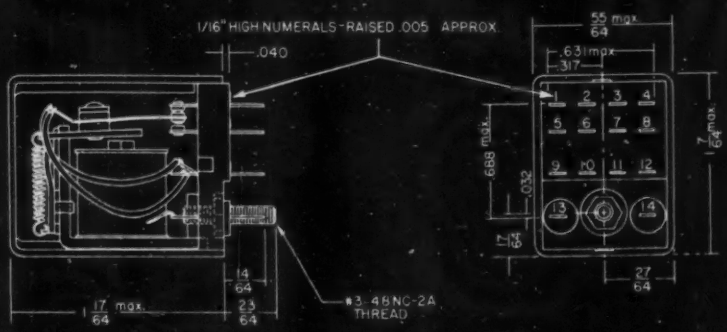
Cutler-Hammer Inc., Milwaukee, Wisconsin • Division: Airborne Instruments Laboratory • Subsidiary: Cutler-Hammer International, C. A. • Associates: Canadian Cutler-Hammer, Ltd.; Cutler-Hammer Mexicana, S. A.

CONTROL

a New and important P&B relay . . .



KHP SERIES SHOWN ACTUAL SIZE



having rare longevity

This small, 4-pole relay has the happy faculty of maintaining its original operating tolerances over an exceptionally long life. Example: tests (by customers!) show this relay has variations in electrical characteristics of less than 5% after more than 100 million operations.

But that's far from all. This is a *small* relay . . . about a one inch cube. This relay is easy to install using the conveniently spaced solder lugs or a socket. Thus you save time and production costs. This relay is versatile . . . its 4PDT contacts will switch loads from dry circuit up to 3 amperes. This relay—well, why not order samples and see for yourself! Order today from your P&B representative or call us at Fulton 5-5251, in Princeton, Indiana.

KHP SERIES SPECIFICATIONS

CONTACTS:
Arrangement: 4 Form C, 2 Form Z.

Material: ½" dia. Silver standard. Silver cadmium oxide and gold alloy available.

Rating: 3 amps @ 30 volts DC or 115 volts AC resistive for 100,000 operations.

COILS:
Resistance: 11,000 ohms max.

Temperature: Operating Ambient: —45°C. to +70°C.

Power: 0.5 watts min. operate @ 25°C. 0.9 watts nom. @ 25°C. 2.0 watts max. @ 25°C.

TIMING VALUES:

Nominal Voltage @ 25°C.	Max. Values
Pull-in time	15 ms
Drop-out time	5 ms

INSULATION RESISTANCE: 1500 megohms min.

DIELECTRIC STRENGTH:
500 Volts RMS 60 cycles between contacts.
1000 Volts RMS 60 cycles between other elements.

MECH. LIFE: In excess of 100 million cycles.

SOCKET: Solder lug or printed circuit terminals. Available as accessory.

DUST COVER: Standard.

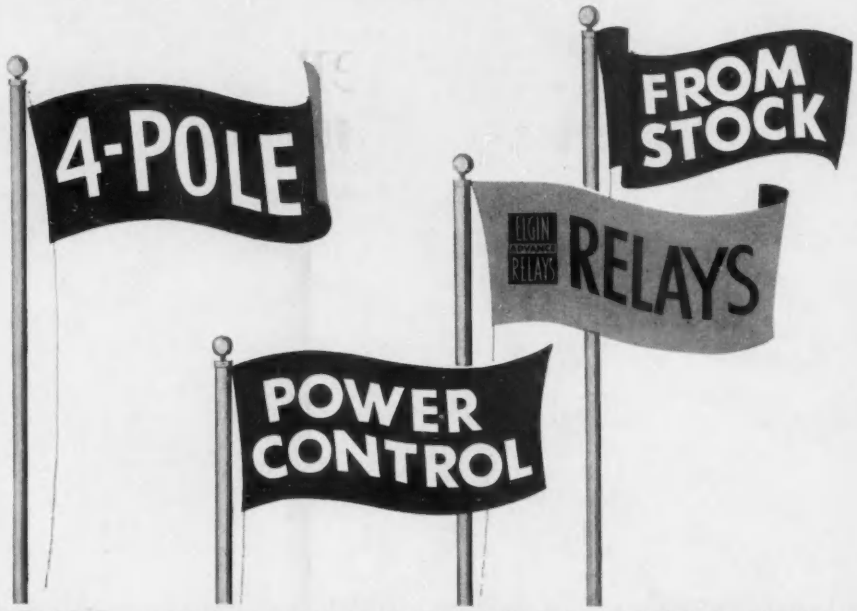
TERMINALS: Solder lug and taper tab.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC PARTS DISTRIBUTOR

POTTER & BRUMFIELD

DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY • PRINCETON, INDIANA

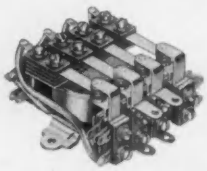
IN CANADA: POTTER & BRUMFIELD, DIVISION OF AMF CANADA LIMITED, GUELPH, ONTARIO



4-POLE POWER CONTROL RELAYS FROM STOCK

Elgin Advance stocks the only 4-pole power control relay of this type on the market. Specify the PC Series when you require dependable current switching.

The PC Series features heavy load carrying capacity, combined with small size—a variety of contact arrangements—and a wide range of AC and DC coil voltages and resistances.

another example of  **reliable relayability**

SPECIFICATIONS

Contact arrangements—SPDT, DPDT, 3PDT, 4PDT
Contact rating—15 amps resistive; 5 amps inductive
Contact material—0.25" dia fine silver
Coil voltages & resistances—wide range of AC and DC
AC power—10-12 VA, nominal
DC power—2-3 watts, nominal
Dimensions—1.906" x 3.062" x 2.593", maximum
Weight—8 ounces, maximum

send for **latest data**

ELGIN advance RELAYS
THE ELECTRONICS DIVISION OF ELGIN NATIONAL WATCH COMPANY
2435 NORTH NAOMI STREET, BURBANK, CALIFORNIA

←CIRCLE 21 ON READER SERVICE CARD

CIRCLE 22 ON READER SERVICE CARD

John C. Lozier
plays chess with the feedback

When John Lozier joined the Bell Telephone Laboratories in 1936, after graduating with a B.A. in physics from Columbia University and a one-year stay at RCA, the telephone company's big project was the first coast-to-coast multichannel carrier system. And the toughest technical problem was how to build consistent amplifiers for the electronic repeater stations that were to relay the telephone signals every 17 miles. Lozier was assigned to the group working on the amplifier and regulation problem, a problem so big that it drew an unusually talented group of scientists who were to become BTL's experts on automatic control, and, incidentally, to make some of the fundamental contributions to control theory.

Working on regulation, Lozier soon became a servo specialist without knowing what the word meant. One of his early contributions, however, was called by Dr. L. A. McColl, in his book *Servomechanisms*, "a novel and excellent procedure for treating oscillating control servomechanisms". What Lozier suggested was that the only effect of the oscillation was to make the on-off servomechanism, basically a nonlinear element, into a linear element, which can then be handled by conventional techniques, thus giving a designer a relatively simple system that can handle large amounts of power.

During World War II, Jack Lozier worked on military control problems, particularly on the guidance of homing devices. His approach was unusual: he recognized that the oscillations of hunting, normally a serious limitation in homing systems, could linearize the system and give it top dynamic performance.

While working on feedback amplifiers, Lozier first became interested in nonlinear elements. The nonlinear system, says the pipe-smoking physicist, offers some significant advantages. In one military project, he says, a nonlinear system was able to control a giant antenna using just one-third the power a linear system would have required.

Lozier's approach to nonlinear control has been dubbed PSAD (pronounced SAD); its key aspects are Prediction, Simulation, Adaption, and Decision. What he is trying to do is dream up a control system that makes full use of what the designer knows about the system and that exploits the full capabilities of a digital computer. To do this he wants to apply a strategy that is as general as possible—nonlinear.

The BTL physicist has the computer do more than just solve an equation. First the computer simulates the control system and its environment. Receiving

initial conditions, the computer tries different moves of elements of the control system, picks the best one, and moves control elements to bring it about.

"It's playing chess with the control system," says Lozier. "All the control system would have to do, it seems to me, is look ahead two or three moves."

Lozier's idea is not radically new; others have also advocated a predictive approach. But what Lozier suggests that is different is a restraint that makes it possible for present high speed computers to solve the simulation problem in real time. Lozier restricts his interest to the error and the first derivative of the error on a phase plane plot instead of attempting to know what happens to all the derivatives.

Whether this approach will work or not still remains to be seen. Lozier is the first to admit he still cannot describe or analyze such a system, but it is the kind of research he feels the control field needs. As president of the American Automatic Control Council, Lozier is trying to help shape the direction of U.S. control research. One thing he feels is needed desperately is a "dean of control" to whom theory research projects would be reported voluntarily so U.S. control engineers might have one central person to question about who is doing what in a specialized area—much as mathematicians used to do with John Von Neuman.

Finding such deans is probably a long way off, he says. To a chess player like Lozier, it would be good strategy and the U.S. will make that move eventually.

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Parameter	Approx. Test Conditions	TI 2N743	TI 2N744	2N834	2N706B	2N708
T_s(nsec)	$I_{B(1)} = -I_{B(2)} = I_C = 10$ ma	14	18	25	25	25
t_{on}(nsec)	$I_{B(1)} = 3$ ma, $I_{B(2)} = -1$ ma, $I_C = 10$ ma	11 (TYP)	10 (TYP)	35	40	35
t_{off}(nsec)		22 (TYP)	25 (TYP)	75	75	75
t_{on}(nsec)	$I_{B(1)} = 40$ ma, $I_{B(2)} = -20$ ma, $I_C = 100$ ma	12 6 (TYP)	12 6 (TYP)	NO SPEC	NO SPEC	NO SPEC
t_{off}(nsec)		40 18 (TYP)	45 23 (TYP)	NO SPEC	NO SPEC	NO SPEC
$V_{CE(sat)}$	$I_B = 1$ ma, $I_C = 10$ ma, $T_A = +170$°C	0.35 v	0.35 v	No High Temp. Guarantee (0.19 v MAX. @ 25°C)	No High Temp. Guarantee (0.4 v MAX. @ 25°C)	No High Temp. Guarantee (0.4 v MAX. @ 25°C)
I_{CEX}	$V_{CE} = 10$ v, $V_{BE} = +0.35$ v, $T_A = 100$°C	30 μa	30 μa	No Guarantee	No Guarantee	10μa (MAX.) @$V_{BE} = +0.25$, $V_{CE} = 20$ v, $T_A = +125$°C

NOTE: All limits are max. unless otherwise noted.

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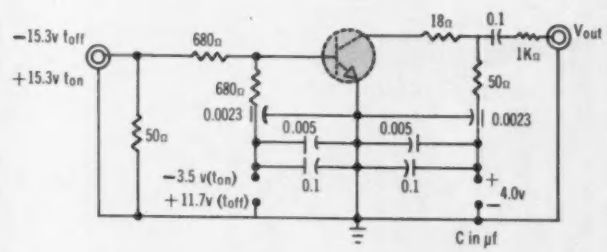


USE THE TI 2N743 TO SWITCH IN 1/3 THE TIME!

2N706
ton = 10 nsecs
toff = 50 nsecs
60

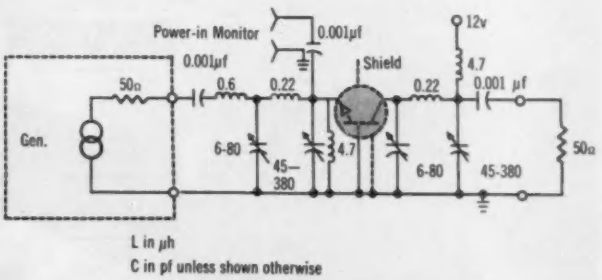
2N743
ton = 7 nsecs
toff = 15 nsecs
22

USE THE TI 2N743 TO DOUBLE POWER OUTPUT AND EFFICIENCY!

2N706
Pout = 225 mw
Eff = 32%
P.G. = 6 db

2N743
Pout = 500 mw
Eff = 65%
P.G. = 6 db

70-mc POWER AMPLIFIER



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Newsbreaks In Control

New Process Computers to Debut

New York—General Electric and TRW Computers Co., already entrants in the process control digital computer field, will announce new machines for control shortly. GE has designed the GE 412—faster, capable of handling more inputs and control outputs, and more expensive than the GE 312—primarily for closed-loop control in the power utility field. TRW Computers has moved the other way: the soon-to-be-announced RW-3100 is a simpler, less expensive machine than the RW-300.

Automation Encyclopedia Planned

Moscow—Pleased with progress in theoretical automatic control studies but dissatisfied with the rate of adoption of new techniques by industry, the Soviets have announced plans to publish an authoritative encyclopedia of Industrial Automation and Electronics, hoping to improve communications between theorists and engineers. V. A. Trapeznikov, Head of the Institute of Automatic Control and Remote Control, and Scientist A. Berg will edit the three volume set. First volume will be published in 1962; the last two in 1963.

Pneumatic Computers Coming

New York—Application of new pneumatic principles to computers has moved a step closer to commercial hardware. AiResearch Mfg. Co. will introduce a new line of analog computing-control systems at the ISA Show in September. Kearfott Div. of General Precision Inc., is developing a pneumatic digital computer that uses a newly devised bistable gas flip flop. Kearfott claims it will be able to package up to 2,000 elements per cubic inch.

Large Automatic Systems Planned in Russia

Moscow—Two giant automatic systems, designed to reduce drastically the size of facility working forces, have been announced in Russia. Automatic control will be applied to an oilfield in Tataria to cut the working staff from 600 to 100. Gas and oil outputs of many wells will be monitored at a central station and action taken—the oil is being forced up by water injection—if the flow drops below prescribed limits. The second system controls irrigation of 9,000 acres of land from a single desk. Operation is automatic, from pumping water from the Syr Darya River through underground pipes to distribution in Uzbekistan cotton fields.

Foxboro and Waugh Merger Set

Los Angeles—Rumors of a pending merger between The Foxboro Co., process control maker, and Waugh Engineering, supplier of metering and blending systems, will be confirmed this month. Waugh, located in Los Angeles, will augment the Foxboro product line and give the Massachusetts-based control maker West Coast engineering strength.

3 new additions to the SPRAGUE MADT* transistor line!

TYPE 2N768

- Micro-energy switch—designed for low current, low voltage, high speed applications
- 10 mc pulse rates, collector currents as low as 1 ma, collector supply voltages as low as 1 volt
- No reduction in switching speed, as with ordinary low current, low voltage devices. Permits higher density packaging
- Typical DC beta of 40 @ $V_{CE} = -0.20$ v, $I_C = -2$ ma

TYPE 2N769

- World's fastest switch—will operate reliably at speeds in excess of 100 mc
- Gain bandwidth product (f_T) typically 900 mc
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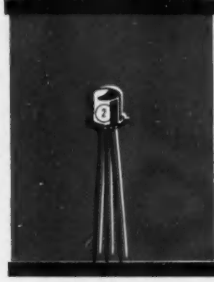

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- Manufactured with tighter parameter control than any other transistor in the industry
- Designed to meet rigid specifications of 16 electrical characteristics—ideal for NOR logic and other super-critical applications
- Low saturation voltage—typically 0.12 volts
- Higher in performance, lower in price than mesa transistors with lesser specifications

High-speed switching transistors in TO-18 cases are now being mass-produced by Sprague. These hermetically-sealed germanium Micro-Alloy Diffused-base Transistors are made by a controlled-etch process to insure extreme uniformity. Maximum frequency capabilities have been improved by graded-base construction. Automated manufacturing techniques have brought about increased production efficiency, permitting favorable reductions in prices. This is why Sprague MADT Transistors can offer you greater performance per dollar than other high-speed devices in low-current switching circuits.

Other Sprague Micro-Alloy Diffused-Base Transistors

TYPE	APPLICATION
2N499	Amplifier, to 100 mc
2N501	Ultra High Speed Switch (Storage Temperature, 85 C)
2N501A	Ultra High Speed Switch (Storage Temperature, 100 C)
2N504	High Gain IF Amplifier
2N588	Oscillator, Amplifier, to 50 mc

For complete engineering information on the types in which you are interested, write Technical Literature Section, Sprague Electric Company, 407 Marshall Street, North Adams, Massachusetts.

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Look for Industrial Uses of Thermoelectrics

DALLAS—

Companies that have been studying the technique of converting heat directly into electrical energy as a power source are now looking for industrial applications. Although there are many obvious possibilities in space vehicles and missiles, the builders of such devices feel they can put these power generating devices to use in industry, too.

At a Thermoelectric Symposium sponsored here by the Department of Defense, the bulk of the papers discussed hardware, in contrast to the last symposium two years ago when most of the papers contained theoretical discussions and plans.

In the military area, Westinghouse Electric Corp. scientists described an experimental generator for a nuclear space vehicle. This prototype removes heat from the reactor cylinder to generate 250 watts of electrical power. Boeing Airplane Co. engineers reported they were building a thermoelectric converter that focused paraboidal mirrors on a thermoelectric junction with two other neighboring mirrors to generate heat.

Experimenters at Radio Corp. of America have built and tested a thermoelectric one-ton air conditioner for submarines.

First big industrial application reported to the symposium was the 100-watt thermoelectric generator delivered to Northern Illinois Gas Co. by Westinghouse for a remote pipeline pumping station. The generator burns propane as a heat source.

But before most industrial customers are ready to accept such devices, symposium attendees agreed, suppliers will have to get prices of equipment down and efficiencies up.

EIA To Collect Industrial Gear Statistics

WASHINGTON—

Electronic Industries Association will start compiling statistical data on sales of industrial electronic equipment this year. A new program established by the Industrial Marketing Data Committee will ask manufacturers to submit data on products grouped in these major categories:

testing and measuring equipment
computing and processing equipment
control and processing equipment
communications and navigation aids
miscellaneous equipment including medical electronics and power supplies

Initially, EIA will collect data in these broad categories. Later, the association plans a refinement of statistical information into more useful product subclassifications.

Continuous Operation Opens The Door for Optical Maser

NEW YORK—

"I am talking over a beam of coherent infrared light", said D. R. Herriot into a telephone handset one day last month. His conversation was the climax of a highly successful test of major significance in data communications. With Dr. Herriot's message, Bell Telephone Laboratories had successfully demonstrated the first generation and application of continuous coherent light.

For almost a year, scientists have been buzzing about coherent light—light generated in such a way that the radiation is in phase and unidirectional. Pioneers at Hughes Aircraft, Bell Labs and IBM have demonstrated workable devices generating coherent light in a crystal material, operating the same way as a microwave maser. But these have all been pulsed sources whose coherent light lasts but milliseconds. Bell Labs new device generates continuous coherent light.

Bell's new laser (light amplification by stimulated electromagnetic radiation) is a radical innovation. Instead of a crystal, it uses a mixture of helium and neon gases through which an electrical discharge flows the same way it flows in a conventional neon tube.

Simply, here is what happens. The energy from the discharge excites helium atoms to an upper "metastable" energy level that has a long time duration. Neon atoms colliding with the excited helium atoms become energized to high energy states, too. Sliding down to a lower state, the neon atoms emit a radiation in the infrared region. This infrared beam, reflecting back and forth inside the glass tube of the discharge, stimulates other excited neon atoms to radiate coherently. Because the discharge activating the helium atoms is continuous, the coherent light is generated continuously.

At each end of the tube is a half silvered mirror that reflects back 99.7 percent of the stimulated infrared. The remaining 0.3 percent that is transmitted is the output of the Bell optical gas maser.

Crystal lasers previously demonstrated have all required some kind of high power pumping—usually a flash tube—to raise the atoms of the structure to an energized state, expending large amounts of power, even for millisecond pulse operation. Bell's gas laser, on the other hand, needs in the order of tens of watts input; its output is about 1/100 watt.

All this means that a new high capacity technique is now available for data transmission. With infrared, Bell scientists believe they can transmit 1,000 times as much information as can be carried by microwave frequencies.

Control Highlights at the IRE Meeting

This year's annual IRE meeting and show (New York, March 20 to 24) shapes up as the biggest in history: 70,000 people are expected to visit the 850 booths and to hear the 275 papers being presented at 54 sessions. And the control engineer's stake continues to increase. Reviewing the program, CONTROL ENGINEERING editors picked out key sessions of interest to those in the control field. In the chart (next page), sessions of broad interest to control engineers are shown in heavy type; sessions of specialized interest are shown in lighter type.

• **Monday**–First session of the meeting is of prime interest to control engineers: it covers discrete and adaptive control systems. The papers tend to describe specific systems rather than to attempt general tutorial approaches. The papers:

On "Bang-Bang" Adaptive Control Systems
by R. E. Kopp

A Statistical Measurement of the Effectiveness of Adaptation in Control Systems
by R. A. Nesbit

An Adaptive System Using Periodic Estimation of the Pulse Transfer Function
by S. C. Bigelow and Herman Ruge

Digital Computers for Stabilizing Control Systems
by William Zdan

Computer Optimization of Nonlinear Control Systems by Means of Digitized Maximum Principle
by S. S. L. Chang

Session 2, Reactor Instrumentation, is of broader interest this year because there are two papers on control problems and two papers on how nuclear radiation affects electronic components and equipments. Six papers are scheduled for presentation in the session; the four of broadest interest:

A Digital Start-up Control Unit for Nuclear Reactors
by J. D. Schmidt, B. K. Eriksen, and W. Peil

Proportional Control of Pressurized Water Reactors
by D. E. Rathbone

Transient Effects of Pulsed Nuclear Radiation on Electronic Parts and Materials
by H. J. Degenhart and W. Schlosser

Problems of Testing Military Computers and Computer Components in Nuclear Radiation Environments
by P. E. Brown and A. L. Long, Jr.

In the electronics industry, one of the most startling phenomena is the continuing invention of radical new devices that increase the capability of electronic circuitry. Reports on some of these, ranging from circuit components to display devices, will be heard in Session 8. Six presentations of interest:

Fundamental Limiting Noise of Depletion Layer Capacitance
by L. J. Giacoletto

Block-Diagram Representation of Junction Diodes and Transistors
by Georg Bruun

Recent Advances in Gallium Arsenide Transistors
by M. E. Jones and E. C. Wurst, Jr.

Uniform Turn-on in Four Layer Diodes
by K. Hubner, M. Melehy, and R. L. Biesele, Jr.

A New High Gain Ultraviolet Detector Tube of High Output Power
by D. H. Howling and R. C. Roxberry

Solid State Display Device
by S. Yando

Other Monday sessions of interest: Session 6 on Product Engineering and Production, primarily because of papers on microminiaturization. One by S. M. Stuhlbarg and L. P. Sweany is called "Microminiature Components and Packaging Techniques"; another is "A Dot Component Packaging System for Electronics", by A. E. Hawley, E. A. Klein, and S. Rubin; a third is "New Developments in Multilayered Etched Circuitry" by N. Schuster and W. Reimann. Session 7 on Advances in Navigation and Flight Safety Systems will cater to the current active interest in tracking systems and improved radar performance.

• **Tuesday**–Starting Tuesday's menu is Session 9 on Control Theory and Practice. Session organizer John Salzer of Thompson Ramo-Wooldridge Co. has aimed for a broad program with no particular emphasis on any one subject. The presentations:

An Extension of Wiener Theory to Multivariable Controls
by L. G. McCracken

Analysis of Linear Control Systems Containing Distributed and Lumped Parameters—a Comparative Study
by O. I. Elgerd

Harmonic Analysis and Describing Function of Nonlinear Systems
by D. M. Makow

Considerations in the Optimum Design of a Precision Radar Track Loop
by S. Adelman

Short Time Stability in Linear Time-Varying Systems
by P. Dorata

In Session 16, a panel of three speakers will discuss another area of new electronic devices: optical masers, electron devices for millimeter-infrared gap, and solid state devices. The speakers will survey the current state of the art, consider application possibilities, and indicate future development potentialities.

Other Tuesday morning sessions of interest to control engineers: Session 10, Nuclear Instrumentation (which will have three papers involving some aspect of data handling); Session 14 on Medical Electronics; and Session 15 called "This World and the Adjacent One", in two parts: lunar exploration and meteorological electronics.

The key session in the afternoon is number 18, Industrial Electronic Applications. Of the four papers, three are in the control field:

Computers for Industrial Control
by R. W. Sonnenfeldt

The Infrared Radiometric Method and its Application to Remote Temperature Measurement
by H. L. Berman

A Phase-Shift Data-Transmission System for Analog to Digital or Digital to Analog Conversion
by H. P. Kilroy

Other sessions of interest to the control field are Session 17, Coding Theory; Session 20, Studies in Magnetic Reading, in which papers describing both analysis of recordings and hardware will be presented; Session 21, the Changing Role of Biomedical Electronics in Science and Technology, a symposium to discuss new equipment and some of the medical problems solvable by electronic instrumentation; Session 22, Implementation of Reliability Predictions; and Session 23, Microwave Devices.

• **Wednesday**–Another key component meeting is Session 27, Application of Solid State Devices as Components. Paper highlights:

CONTROL ENGINEER'S GUIDE TO 1961 IRE MEETING

	WALDORF ASTORIA HOTEL			NEW YORK COLISEUM		
Monday, March 20 2:30 to 5:00 pm	STARLIGHT ROOF: **Session 1—Discrete and Adaptive Control Systems**	ASTOR GALLERY: **Session 2—Reactor Instrumentation**		FARADAY HALL: Session 6—Product Engineering and Production	MARCONI HALL: Session 7—Advances in Navigation and Flight Safety Systems	MORSE HALL: **Session 8—Electron Devices**
Tuesday, March 21 10:00 am to 12:30 pm	STARLIGHT ROOF: **Session 9—Control Theory and Practice**	ASTOR GALLERY: Session 10—Nuclear Instrumentation		FARADAY HALL: Session 14—Medical Electronics	MARCONI HALL: Session 15—This World and the Adjacent One	MORSE HALL: **Session 16—Broadening Device Horizons**
2:30 pm to 5:00 pm	STARLIGHT ROOF: Session 17—Coding Theory	ASTOR GALLERY: **Session 18—Industrial Electronics Applications**	SERT ROOM: Session 20—Studies in Magnetic Reading	FARADAY HALL: Session 21—The Changing Role of Biomedical Electronics in Science and Technology	MARCONI HALL: Session 22—Implementation of Reliability Predictions	MORSE HALL: Session 23—Microwave Devices
8:00 pm to 10:30 pm	GRAND BALLROOM: Session 24—Panel: New Energy Sources.					
Wednesday, March 22 10:00 am to 12:30 pm	JADE ROOM: **Session 27—Application of Solid State Devices as Components**	SERT ROOM: Session 28—Space Electronics		MARCONI HALL: Session 31—Mathematical Approach to Reliability Prediction	MORSE HALL: Session 32—Microwave Solid State	
2:30 pm to 5:00 pm	STARLIGHT ROOF: **Session 33—Data Recording and Storage**	JADE ROOM: **Session 35—Advances in Component Design**	SERT ROOM: Session 36—Telemetry	MORSE HALL: Session 39—Microwave measurements		
Thursday, March 23 10:00 am to 12:30 pm	STARLIGHT ROOF: **Session 40—Analog and Hybrid Techniques**	EMPIRE ROOM: Session 44—Space Communication Systems of the Future		FARADAY HALL: Session 45—Human Factors in Electronics	MORSE HALL: Session 47—Advances in Instrument Calibration and Precision	
2:30 pm to 5:00 pm	STARLIGHT ROOF: **Session 48—Digital Computer Techniques**			MORSE HALL: **Session 54—Advances in Instrumentation Techniques and systems**		

Silicon Oxide Capacitor
by O. B. Cecil
New Concepts in Thermoelectric Device Design
by W. H. Clingman
Ceramic-Metallizing Tape for Reliable Metal-Ceramic Sealing
by H. D. Doolittle, K. Ettre, R. F. Spurck, and P. F. Veradi
A Ceramic Band-Pass Transformer and Filter Element
by A. Lungo and F. Sauerland

Other Wednesday morning sessions impinging on the control field: Session 28, Space Electronics; Session 31, Mathematical Approach to Reliability Prediction; and Session 32, Microwave Solid State.

Wednesday afternoon will see an important session on Data Recording and Storage and one on Advances in Component Design. The latter will feature two reports on the Signal Corps microminiaturization program. They are:

Materials and Form Factors for Micromodule Inductors
by G. G. Hauser
Micromodule Reliability Status Report
by D. T. Levy

Also Wednesday afternoon are sessions on Telemetry and Microwave Measurements.

• **Thursday**—Session 40, Analog and Hybrid Techniques stacks up as an exceptionally interesting one for control engineers working on advanced systems. The papers range from combined analog-digital real-time computation to a tunnel diode function generator. The presentations:

A Simulator for the Evaluation of Electromagnetic Systems
by L. G. Fischer and F. S. Barbeck
Theory and Practice of Hall Effect Multipliers
by G. S. Glinski and J. P. Landolt
A Tunnel Diode Function Generator
by P. Spiegel
Stabilized Synchro to Digital Converter
by M. Masel and D. Blauvelt
Real-Time Analog-Digital Computation
by M. E. Connelly
Obtaining the Frequency Response of Physical Systems by Analog Computer Techniques
by G. W. Ogar

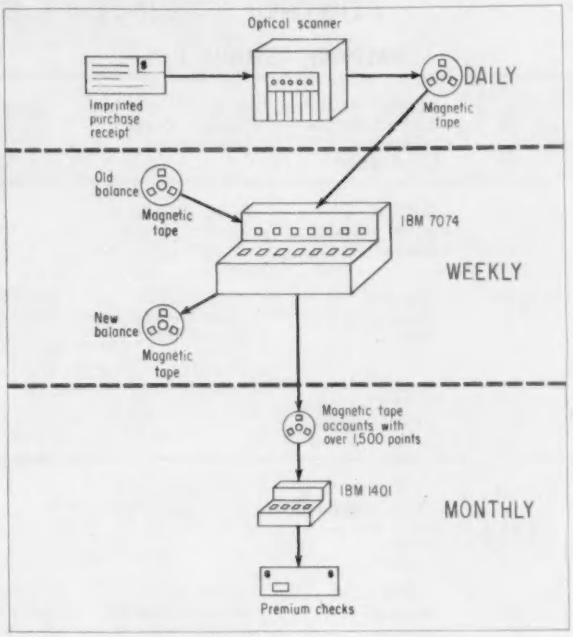
Other sessions worth noting: Session 44, Space Communications; Session 45, Human Factors in Electronics; and Session 47, Advances in Instrument Calibration and Precision.

Digital Computer Techniques headline the Thursday afternoon's technical offerings. The program for Session 48:

On a Random Walk Related to a Nonlinear Learning Model
by L. Kanal
A Systematic Method for Computer Simplification of Logic Diagrams
by F. A. Rocket
Design of Computer Circuits Using Linear Programming Techniques
by G. H. Goldstick
Systematically Introduced Redundancy in Logical Systems
by W. C. Mann
Majority Gate Logic for Improved Digital Reliability
by G. Buzzell
Tunnel Diode Threshold Logic
by G. P. Sarrafian

Trading Stamps Bow to Automatic Data Processing System

A Texas company puts the full power of computer technology to work to end some of the complaints by merchants about trading stamps.



DALLAS—

The diagram above shows how consumers in Texas and Oklahoma will earn premiums they usually get with trading stamps without collecting and pasting stamps in books. American Premium Systems Inc. will introduce the radical approach in a test starting in March. Instead of trading stamps, APS will depend on an automatic electronic data processing system.

Under the system, when a consumer makes a purchase, he gives the retailer a plastic card, like a charge plate, which the merchant puts in an imprinter. In one motion the storekeeper records the customer's name, address and number of points earned by the purchase. Daily the merchant sends copies of these sheets to a centralized data processing center where they are stored on magnetic tape. When a customer earns 1,500 points, the data center automatically sends the customer a premium check that can be redeemed for merchandise.

From the time the envelope with the imprinted sheets is opened at the data center until a premium check is mailed the system is automatic. Two computers and an optical reader are used.

• **Why electronics**—APS introduced the system to do away with some common complaints about trading stamps. One is the bother to the customer of saving and pasting the stamps into books. But more annoying has been the expense to the retailer. The merchant has to buy trading stamps in advance and bear the risk of loss, theft, or damage to his stock of stamps. In addition, the storekeeper frequently gives stamps to people who don't save them, an expense to him but a windfall to the stamp company. With the APS system, the merchant will not pay for points until he issues them.

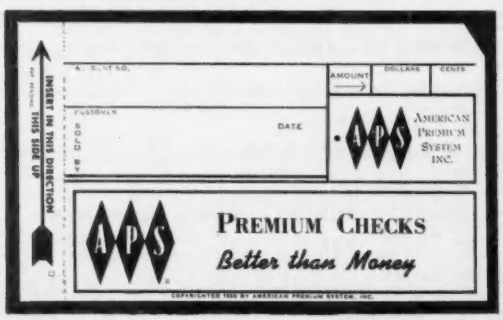
Bulk of the data processing will be performed on an IBM 7074, but certain operations, such as the preparation of plastic plates for new customers and the preparation of premium checks will be done on the IBM 1401.

To join the system, a consumer sends an application to APS or one of the member merchants. The application is forwarded to the data processing center where it is put on a punched card and assigned an account number. The card goes into the 1401 computer which assigns codes to the account, sorts the accounts into numerical sequence, and files the information on magnetic tape.

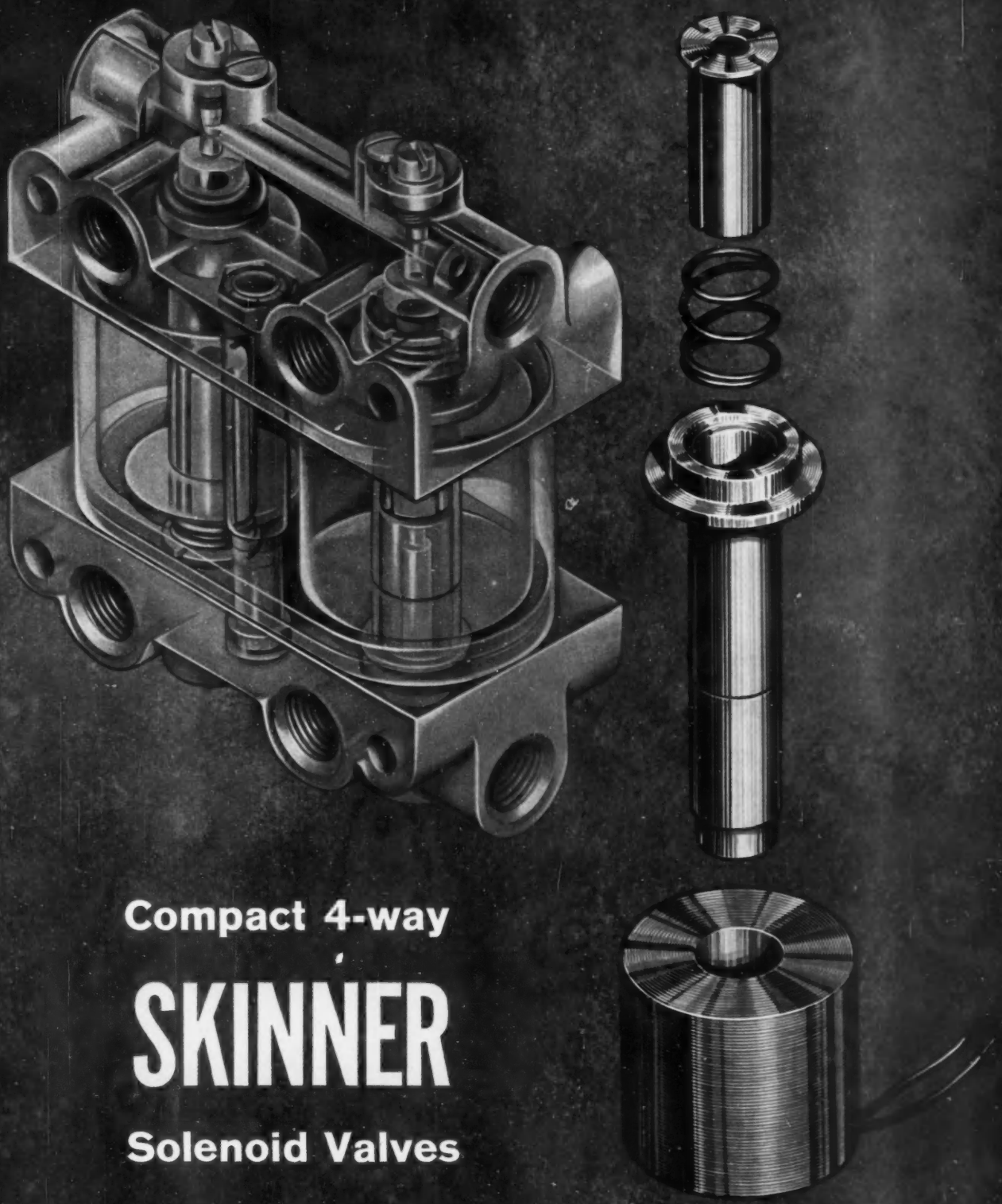
This tape serves as input to the 7074 machine which sorts and files the entries into state, city, and zone account sequence. This tape is then input back to the IBM 1401 to produce a punched tape that runs an embosser to make the plastic identification card for the customer.

• **Collecting points**—With the plastic card, the customer is ready to start

Read automatically



Printed and mailed automatically



Compact 4-way

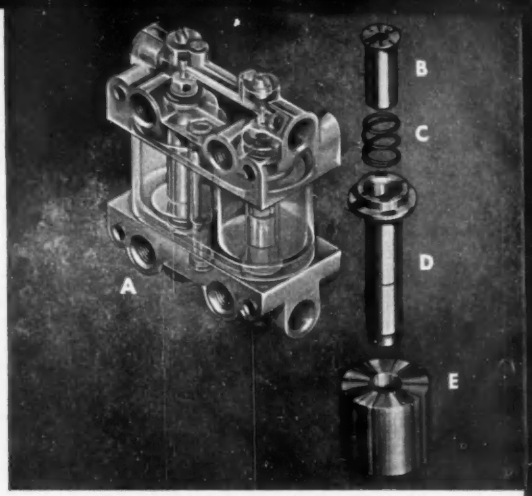
SKINNER

Solenoid Valves

assure precise cylinder control

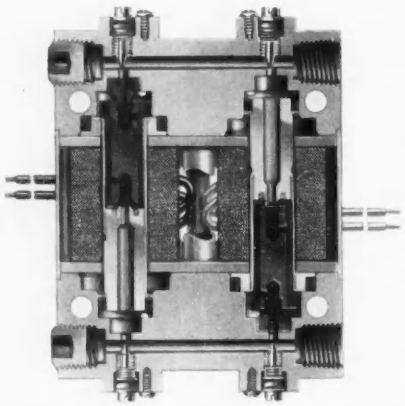
Here's how accurate, dependable operation is built into SKINNER 4-way solenoid valves

- **Precise flow control**—by adjustable metering
- **Compact, direct acting**—two 3-way valves in one housing
- **Durable and corrosion resistant**—stainless steel internal parts
- **Leakproof, bubbletight sealing**—soft, synthetic inserts
- **Positive operation mounted in any position**—spring-loaded plungers
- **Underwriters approved**—wide selection of coils, voltages and frequencies
- **Wired from front or rear**—housing easily reversed
- **Adaptable to many uses**—optional porting arrangements



A. Transparent view of 4-way solenoid valve B. Plunger C. Plunger return spring D. Sleeve E. Coil

SKINNER four-way solenoid valves available in three basic types



The Skinner V9 solenoid valve is two 3-way valves in one compact housing. Both valves may be independently controlled and metered to provide accurate, dependable control of single- or double-acting cylinders, or larger pilot-operated valves.

V9 types are available without adjustable flow and with metering at both exhaust ports, both inlet ports or full metering of all ports.

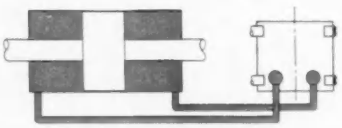
▪ ▪ ▪

For complete information, contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

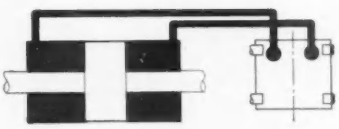
V9 SERIES SPECIFICATIONS

Media—air, hydraulic oils, inert gases
Orifice Diameter—$\frac{3}{64}$", $\frac{1}{16}$", $\frac{3}{32}$", $\frac{1}{8}$"
Pipe Size—$\frac{1}{4}$" NPTF
Maximum Operating Pressure Differential—0 to 150 PSI (up to 225 PSI also available)
Temperature Range—minus 40°F. to plus 180°F.
C_v Factor—$\frac{3}{64}$" .052, $\frac{1}{16}$" .095, $\frac{3}{32}$" .156, $\frac{1}{8}$" .214
Mounting—$\frac{1}{4}$" through-bolt holes.

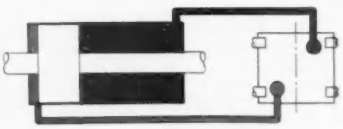
Normally closed—normally closed V933 valves with a neutral position. Generally applied on double-acting cylinders where the piston is in a neutral position without pressure when both coils are de-energized. This permits manual shifting of the piston without operating the valve.



Normally open—normally open V955 valves with a neutral position. Generally applied on double-acting cylinders where both sides of the piston are to be open to pressure when both coils are de-energized. Under certain conditions, the first operating stroke of double-acting cylinders will be smoother with this valve in use.



Normally closed—normally open V935 valves with no neutral position. Generally applied on double-acting cylinders where the piston is to be in retracted or extended position with pressure when both coils are de-energized. Wiring is simple—both coils are operated simultaneously and can be controlled by one single-pole, single-throw switch.



When you specify solenoid valves, specify Skinner. Skinner solenoid valves are distributed nationally.

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SKINNER ELECTRIC VALVE DIVISION
SKINNER PRECISION INDUSTRIES, INC. • NEW BRITAIN, CONNECTICUT, U.S.A.

PRINTED IN U.S.A.

collecting points. When a card carrier makes a purchase at a member store, his card is inserted into an imprinter which records on an APS form the name, address, account number of the customer, and the dollar amount of the purchase.

At the end of the day, the merchant sends these slips to the APS data center where they are automatically read on an IBM optical reader which puts the account number, account name and address, and amount of purchase on magnetic tape.

Once a week the daily tapes are run through the big computer and merged into a single tape which files the transactions in numerical account sequence. Another magnetic tape containing the previous week's balance is inserted to the computer and the week's transactions added and put on still a third magnetic tape.

As the computer adds the new transactions to the old record, it watches for totals that pass 1,500 points, sets up a separate magnetic tape file of account numbers, names, and addresses of those customers who collect that many points, and files the data on magnetic tape. Once a month, this tape is run through the 1401 machine which then prints out and puts into the mail the 1,500 point dividend checks. A consumer can redeem these premium checks at any member store.

The two computer system has been programmed to handle 2,000,000 active accounts. During the test, data processing will be performed at IBM's Service Bureau in Chicago. APS already has plans to extend its point promotion on a national scale. The company has ordered $3 million worth of computer equipment to handle 6 million customer accounts.

When the test starts in March, IBM will not yet have delivered any 7074 machines, which are a modification of the IBM 7070 computer. Therefore, during the test, the Service Bureau will process APS premiums on an IBM 7070, which can use the same program as the 7074.

Main reason for APS' choice of the modification is the 7074s capacity for on-line processing. And the 7074 is twice as fast as the 7070 when it comes to processing business data. Its rental is about 22 percent higher than the standard IBM 7070 computer.

One interesting aspect of APS's own data center is that the company is buying its computers and peripheral equipment—not renting them.

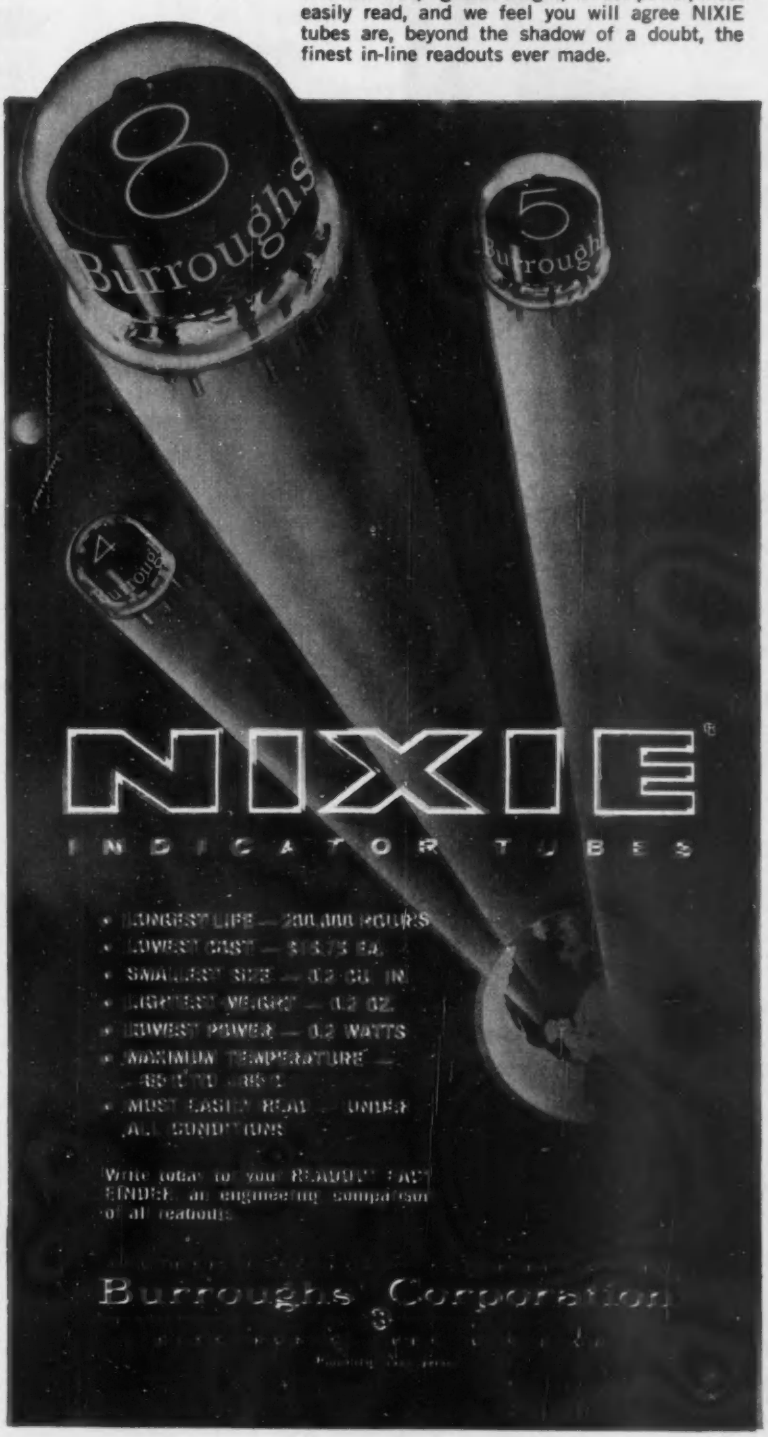
—Marvin Reid
McGraw-Hill News

READOUT OF THIS WORLD

DOWN-TO-EARTH FACTS

A three year test proves that our ultra long life NIXIE® Indicator Tubes have 100 times longer life than any other electronic readout.

Consider this, then add the factors of lowest cost, smallest size, lightest weight, lowest power, most easily read, and we feel you will agree NIXIE tubes are, beyond the shadow of a doubt, the finest in-line readouts ever made.



← CIRCLE 34 ON READER SERVICE CARD

CIRCLE 35 ON READER SERVICE CARD

New operational amplifier

200 KC

gain-bandwidth product

from unity to open loop

COMPACT . . . ALL SOLID STATE
FULL DIFFERENTIAL

RIG's new, transistorized Operational Amplifier Model A-2 is *now your one-best DC amplifier choice*: as a miniature, completely reliable instrument pre-amplifier . . . for versatile, multiple-unit use in complex data-handling and process control systems . . . and for customary analog computing applications.

Check and *compare* the A-2's unmatched combination of electrical, mechanical, and cost specifications:

OPEN LOOP GAIN — 100,000
RISE TIME — Less than 10 microseconds at unity gain, and at gain of ten; less than 100 microseconds at gain of one hundred.
DRIFT (referred to input) — Less than two millivolts over 75°F to 120°F change of ambient; less than 100 microvolts over eight-hour period at constant temperature.
COMMON-MODE REJECTION RATIO — Up to 500,000 to one at open loop.
OUTPUT LOADING CAPABILITY 10K at ± 10 volts.
LINEARITY — Within 0.1% in output swing of ± 10 volts.
SIZE — 5¼" x 2½" x 1¼"
WEIGHT — 12 oz. COST — $195.00

Request RIG-AMP Technical Bulletin for complete details.

ALSO AVAILABLE. Companion, plug-in Power Booster for use with Amplifier A-2 in driving heavy instrument systems, rotary amplifiers, and small DC servos.

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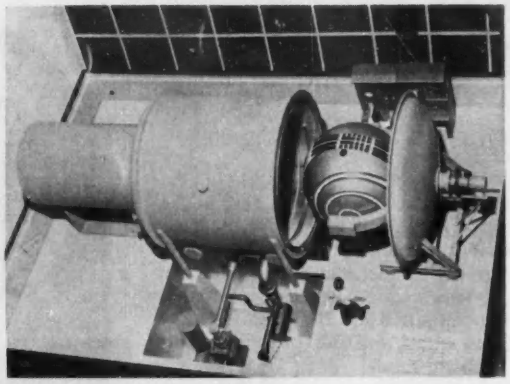
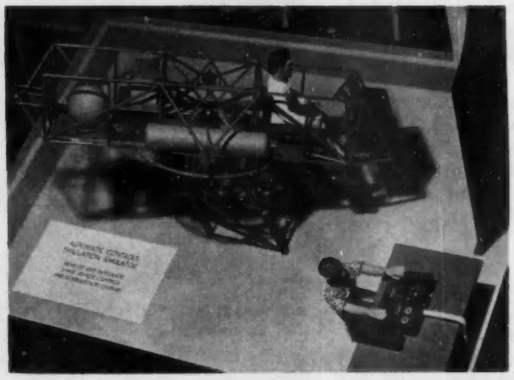
SPECIAL-PURPOSE ANALOG COMPUTERS FOR DATA HANDLING AND CONTROL, ELECTRONIC COMPONENTS, NMR AND ESR SPECTROMETERS, MAGNETIC RESONANCE ANALYTICAL SERVICES

SIMULATION — Key Topic at AAS Meeting



Space environment simulator



Automatic controls simulator

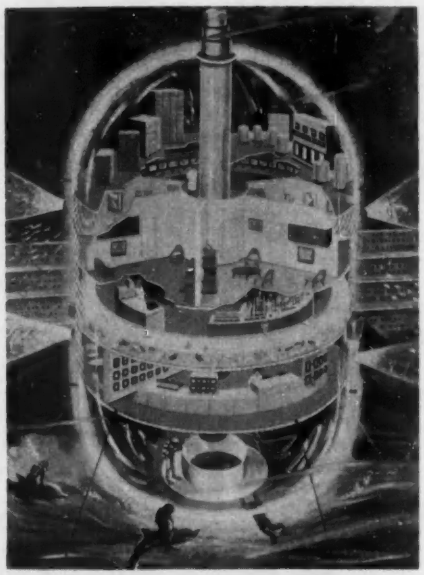
American Astronautical Society reviews some startling advances in simulators.

DALLAS—

Ignoring the vocal controversy ranging over the need (or lack of a need) for a reappraisal of the nation's space efforts, attendees at the American Astronautical Society annual meeting (January 16-18) heard some announcements of intriguing advances in simulators. The photos show some of the projects discussed.

Chance Vought Corp., for example, said it plans to make its Dallas plant a "space on Earth" simulator center. The Martin Co. displayed a model of a Lunar Housing Simulator. And General Electric showed off plans for an underwater container that would allow persons to simulate life in space.

C-V will install "within a few months" a manned space flight simu-



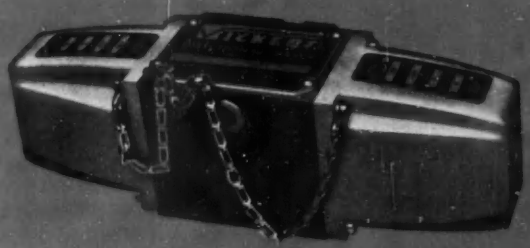
Space simulator underwater

Improved reliability • Greater capacity • No increase in price

NEW DIRECTIONAL VALVE DESIGNS

WITH VICKERS Q-E-L* SOLENOIDS

- New Q-E-L* solenoids assure quiet, cool operation plus shock-free performance through superior cushioning.
- Four to five times more cycle life than previously obtainable with ordinary air-cooled solenoids.
- Capacity increased from 50 to 500% on new designs.
- All models suitable for pressures to 3000 psi.
- Complete range of sizes available for maximum flows to 440 gpm.



MODEL DG4S4 is rated at 8 gpm (with nominal pressure drop) with a maximum allowable capacity of 12 gpm without malfunction. Maximum recommended operating pressure is 3000 psi. Standard subplates are available with ⅜ in. or ½ in. pipe thread ports. SAE straight thread port connections can also be provided.

MODEL DG5S4 solenoid-controlled, pilot-operated valve is rated at 30 gpm (with nominal pressure drop) with a maximum capacity of 80 gpm without malfunction, depending on circuit conditions and valve type. Standard subplates are available with ¾-in. and 1 in. pipe thread connections. SAE straight thread port connections can also be provided. Write for Catalog 5001-C.

8596

* Q-E-L designates Quiet Extended Life solenoid—a *Vickers exclusive.*

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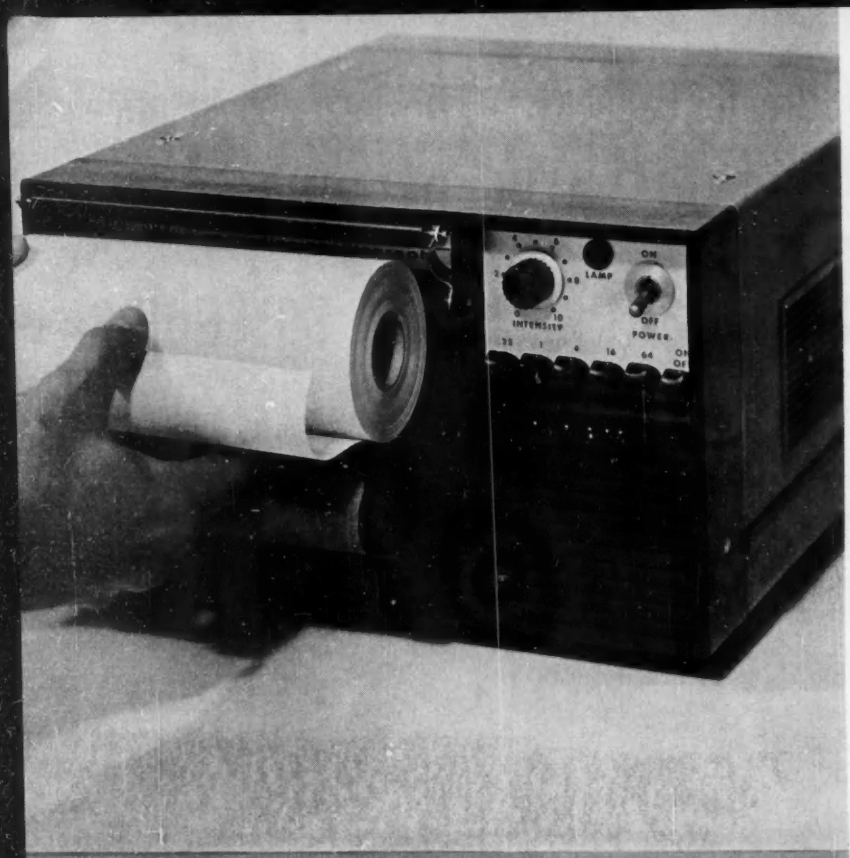
Department 1606 • Detroit 32, Michigan



Easiest loading...

CEC's 5-124 Recording Oscillograph is ready to record in just 10 seconds

Drop in a roll of paper... at the push of a button you are ready to record up to 18 channels of data... push another button to select any of five recording speeds ranging from ¼ to 64 ips. CEC makes recording easier than ever before with the new portable 5-124 Recording Oscillograph—a "big" oscillograph that sells for considerably less than the cost of any comparable instrument.

Everything you need for loading, operating and viewing is right in front of you—including ready to read, print-out records that eliminate processing problems.

The 5-124 delivers a writing speed of 50,000 ips with trace widths of 0.010" or less—and an optional DATAFLASH* unit can speed its print-out process by a factor of 60!

For flexibility, the 5-124 has 18 individual inputs and is available with many optional features to meet your most demanding data recording needs.

For complete information, call your nearest CEC sales and service office or write for Bulletin CEC 5124-X8.

*Pat. Pend.

Data Recorders Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

A SUBSIDIARY OF Bell & Howell · FINER PRODUCTS THROUGH IMAGINATION

WHAT'S NEW

lator, a space environment simulator, and an automatic controls evaluation simulator. The flight simulator will duplicate such space missions as Earth orbiting and landing, lunar and interplanetary flights, rendezvousing with a satellite, lunar parking orbits, lunar landings and launchings. The brains for this facility will be furnished by the company's digital-analog computer complex.

The space environment unit will help develop and test satellites, vehicles, and systems under conditions of vacuum, extreme cold, and intense sunlight. It will simulate altitudes over 200 miles above Earth, plunge temperatures to −320 degrees, and duplicate the sun's radiation spectrum.

The automatic controls evaluation simulator will test automatic control systems for both manned and unmanned space vehicles. It will be a structure floating on a nearly frictionless cushion of air, and will help develop and integrate systems to stabilize or control space vehicles.

• **Martin's shell**—Martin's Lunar Housing Simulator, according to present plans, will be a 35-ft diameter unit consisting of an outer spherical shell containing an inner spherical chamber. It will duplicate, as nearly as possible, living conditions in a lunar base. The inner chamber will have four levels, with an inner central core providing access to them. The core will open to both the space between the spheres and to the outside through an air lock.

A somewhat similar proposal—with the exception that it would be built underwater—was described by GE.

• **Needs for simulation**—Some of the experiments that dictate such extraordinary simulation facilities were also discussed. For example, General Electric reported it had successfully inflated a plastic covering with foam plastic under simulated space conditions. Such experiments could mean safer escape systems for manned satellites and improved thermal shielding.

John J. Konikoff, a GE scientist, described a system for generating oxygen for space travelers. Applying the Fischer-Tropsch synthesis—to convert carbon dioxide to water and methane, Konikoff's equipment decomposes water electrically to release oxygen.

Outside the simulation area, Northrop Corp. announced that its engineers have made direct measurement of continuous thrust from a magnetogasdynamics engine, one of the exotic power plants that someday may drive space vehicles.

←CIRCLE 38 ON READER SERVICE CARD

Retailers Hunt The Perfect Input Device

NEW YORK—

"For three years, without much success, we've been trying to sell electronic equipment to merchandising organizations. We are finally starting to get some receptive responses. Mechanization at the selling level is about to win acceptance." That was the opinion expressed by a veteran sales manager after unexpected, but highly gratifying, interest was shown at the exhibits set up in conjunction with the convention of the National Retail Merchants Association.

The influx of data processing equipment suppliers was an indication that change is afoot. Among the exhibitors: IBM, Burroughs Corp., and National Cash Register, showing computers; Farrington Mfg. Co., an optical reader; Dashew Business Machines, Inc., Addressograph-Multigraph, Denison Mfg. Co., and A. Kimball, mechanized systems for speeding paper work.

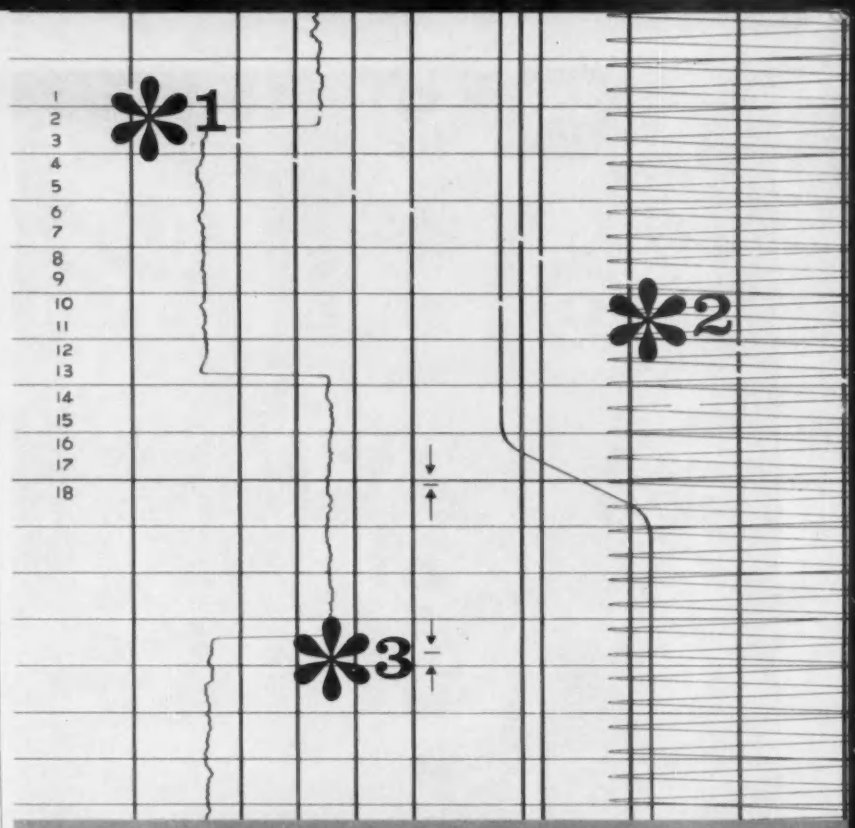
Most serious inquiries seem to come from those retailers who had already successfully installed electronic data processing systems and were now trying to tie their selling operations to the computer. Farrington Mfg. Co., for example, displayed a system that started with a sales floor imprinter which printed a record of the sales transaction for an optical scanner to read and convert into disital computer format.

Addressograph-Multigraph showed a sales imprinter on which a sales clerk can imprint customer's name, address, account number, amount of sale, type of sale, department, and clerk identification for automatic reading by an optical device. Dashew showed a device for the sale floor that printed and perforated a tab card with information on every transaction.

What retailers are looking for, however, is a simple device that a clerk can use to speed up preparation of the paper work on a sale, so the clerk spends more time selling and less time filling out sales slips. And the retailers want something that will fit into the computer system so store management has better control of inventory and can easily spot significant sales trends.

The big obstacle so far is cost. Most department stores have a large investment in cash registers and the store excutives don't want to throw these machines out. "Ideally", said one executive, "we'd like to be able to key tap all this data on a cash register. If the cash registers *have* to go, we want to replace them with this perfect input device whose cost would be very much less than a register."

CIRCLE 39 ON READER SERVICE CARD →



fastest reading!

Here's 50,000 ips writing speed with the results at your fingertips

The print-out record shown here illustrates a typical dynamic test employing 15 traces. Take special note of:

*** 1 – Trace numbering * 2 – Trace interruption**

*** 3 – Full-width timing lines (0.01, 0.1 or 1.0 sec. intervals)**

Trace identification and timing lines are optional features, as are grid lines (1/10" or mm) and galvanometer block heaters. Eighteen Type 7-300 Galvanometers are available covering a range of 1.62 microamps per inch at 6 cps and 46.1 milliamps per inch at 5000 cps.

CHECK THESE STANDARD FEATURES... ALL INCLUDED IN THE BASIC 18-TRACE TYPE 5-124 SELLING FOR $2,290

5 Pushbutton-selected speeds • 7" by 200' print-out record capacity • High intensity mercury-vapor light source • Automatically regulated galvanometer lamp circuit • Intensity control • Unexposed footage indicator • Individual input connectors • 15¼" long x 13" wide x 7⅝" high • 115 volts, 60 cps, 250 watts

For complete information, call your nearest CEC sales and service office or write for Bulletin CEC 5124-X8.

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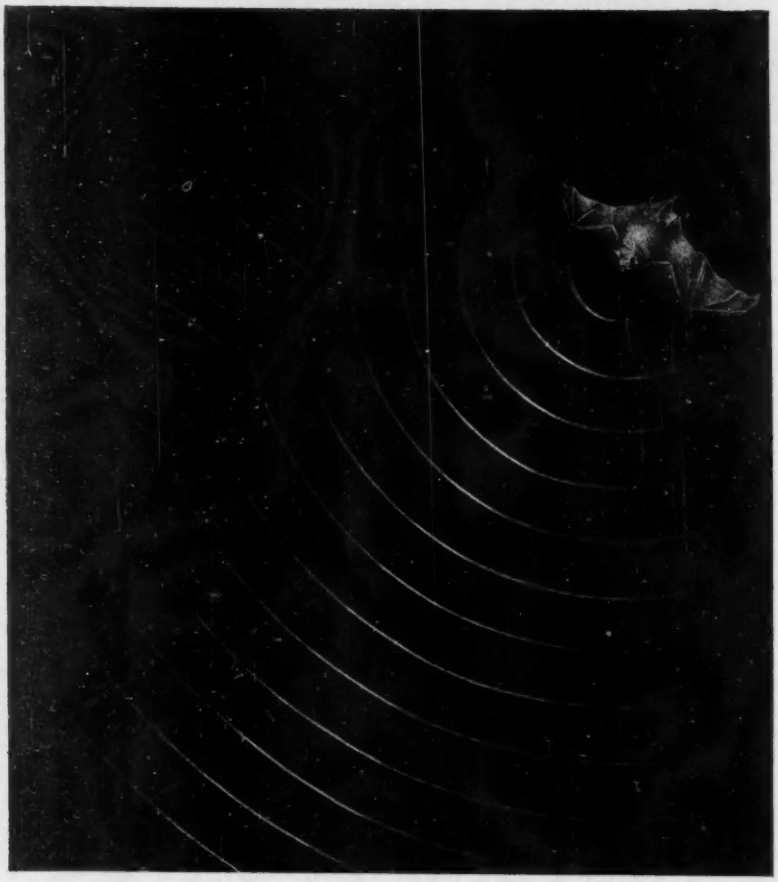

how to capture a bat – underwater – with a PI tape recorder

To satisfy a yen for sea food, a particularly interesting member of the bat family catches fresh fish by reaching beneath the surface. In studying these bats, Harvard Professor Donald R. Griffin captures the bat's "radar" with a microphone in the air and a hydrophone in the water. The pulses of sound are recorded on alternate channels of a PI tape recorder, and played back at reduced speeds so that the original frequencies, 15 to 200 kilocycles, become audible.

In other studies, Professor Griffin has captured bat sounds in stereo. Using a pair of microphones located at different points, he has recorded and measured the arrival time of sound pulses to determine the bat's changing position with respect to the two microphones.

For capturing bat sounds and other dynamic phenomena for conversion to electrical form, PI recorders offer a number of distinct advantages over conventional instrumentation magnetic tape recorders. A brief note from you will capture the details.

P.I. Invites inquiries from senior engineers seeking a challenging future.

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REPRESENTATIVES IN PRINCIPAL CITIES THROUGHOUT THE WORLD

40 CIRCLE 40 ON READER SERVICE CARD

WHAT'S NEW

Fourteen-Computer Net To Speed Data Flow

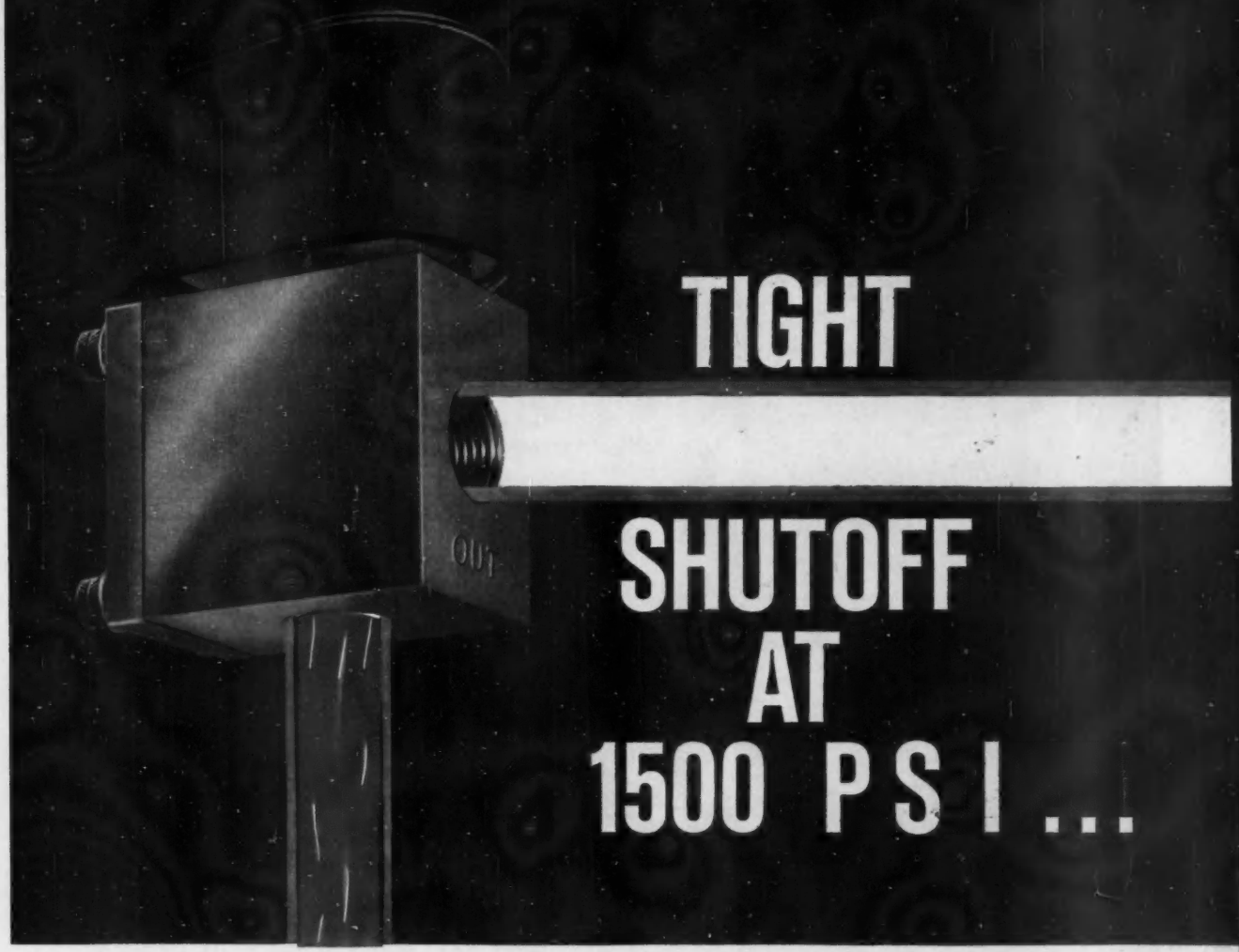
Hughes Aircraft starts installing 14 IBM 1401 computers to work with a central IBM 7090 machine; company-wide control of production, inventory and purchasing paperwork will save $600,000 per year.

CULVER CITY, CALIF.—Hughes Aircraft Co. has started installation of the biggest net of satellite computers ever used to monitor and control business functions. Starting this month, Hughes is installing one IBM 1401 a month until a total of 14 machines are in place, each in a separate division of the company. With the company's IBM 7090, the satellite computers will work in five areas: product definition, material control, fabrication and assembly scheduling control, finished inventory and shipping, and manufacturing cost accumulation.

Faced with a general reduction in profit margins because of rising operational costs, Hughes set six separate teams to studying the prospects for electronic data processing. Promising ideas from each group were tried out at Hughes El Segundo facility, a plant that employs 3,500 people to manufacture military electronic systems. Last February a comprehensive information system was installed; during the next 10 months of 1960 it saved $300,000 in direct costs at the one facility. Impressed by such a cost reduction, Hughes decided to implement the system company-wide.

• **Product definition**—First job of the network is to supply engineering design information to factory and support personnel in meaningful terms. At the El Segundo plant, for example, Hughes buys 15,000 parts from outside suppliers and makes another 15,000 components to build 1,000 different end items. The IBM 1401 and 7090 computers work together to turn out a master parts list in machine language.

Identical tapes, containing minimum basic information, are prepared and forwarded to factory and support groups; then additional breakdowns are prepared by the 1401 machine as required. Previously, the engineering department had to send blueprints of each end product to four different departments, each of which manually prepared a different parts list. Clerks copied parts information so that it



TIGHT SHUTOFF AT 1500 PSI ...

WITH ASCO'S 2-WAY HIGH PRESSURE SOLENOID VALVES

The ASCO Bulletin 8223 solenoid valve is a heavy-duty type designed for tight shutoff at high pressures. It is especially suited to hydraulic applications, such as hydraulic lifts and elevators — and missile launching platforms.

Features:

- **Operates in any position**
- **Operating Characteristics:** Pressures to 1500 PSI. Temperatures to 200°F. Pipe Sizes—½" to ¾".
- **Low Power Consumption:** Continuous Duty Coils rated 10 watts D-C; 10.5 watts A-C.
- **Standard, Watertight or Explosion Proof Solenoid Enclosures:** May be rotated 360° for easy installation.
- **Large flow capacity:** Valve will handle air, gas, water, light oil and other non-corrosive fluids. Available normally closed, valve features teflon disc and stainless steel magnetic parts.

For Pressures to 3000 PSI: Modified designs are available, suitable for handling nitrogen, hydrogen and oxygen at temperatures to minus 350°F. Furnished in ¼" to 1" sizes, valves can be supplied with explosion proof solenoids, and may be designed for operation on 24 volts D-C or other voltages as required.

These all stainless steel valves are especially suited for use on missile ground support equipment.

New! Catalog No. 202 covers the ASCO line of Solenoid Valves. Write for your copy today.

For Immediate Delivery . . .

World's largest stock of Solenoid Valves. A complete Solenoid Valve Stock List will be sent to you with your copy of Catalog No. 202.

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CIRCLE 41 ON READER SERVICE CARD

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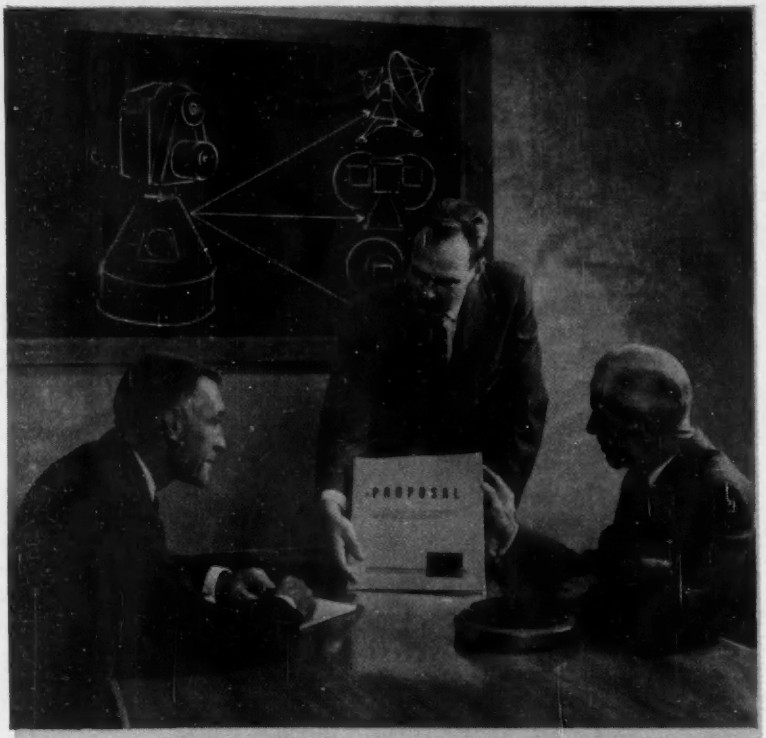
AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

ENGINEERING
REPORT
ON BENDIX COMPONENTS



HOW MUCH CAN BENDIX SAVE YOU IN ANTENNA PEDESTALS?

GET OUR SPECIFIC ENGINEERING PROPOSAL

Bendix experience in ground radar pedestal design, manufacture and installation can benefit *you*. It can meet your requirements without delay. Since basic design and tooling have already been accomplished, modifications, for your prototype needs, can be made quickly—and with important savings—or, we can design a completely new pedestal to meet your specific needs.

Bendix ground-installation radar pedestals are lightweight, compact, air transportable. They possess a high degree of accuracy, and have been completely proved in the field. Bendix also is widely experienced in airborne radar systems for weather and target tracking purposes.

If these demonstrated radar capabilities meet your needs, write today for further information, including a *specific engineering proposal*. What are your requirements?

EXAMPLES OF APPLICATIONS:

Weather Radar • Storm Detection • Meteorological Tracking • Mortar Tracking • Electronic Countermeasure • Satellite Tracking • Drone Surveillance • Telemetering

Eclipse-Pioneer Division
Teterboro, N. J.

Bendix THE BENDIX CORPORATION

District Offices: Burbank, and San Francisco, Calif.; Seattle, Wash.; Dayton, Ohio; and Washington, D.C.
Export Sales & Service: Bendix International, 205 E. 42nd St., New York 17, N. Y.

WHAT'S NEW

could be entered on punched cards.

• **Material control**—Once the master parts list is prepared, subsequent computer operations explode each item into its component parts, review related manufacturing schedules, and then spell out a parts requirement schedule—with quantity and lead time indicated. In addition, the computer will compare the number of parts required with the inventory, advising which parts should be purchased.

At first, purchasing orders will be prepared manually on Flexowriters (supplementary outputs: punched cards for receiving and inspection and accounts payable departments; a punched tape to write repeat orders automatically). But Hughes is experimenting with computer-written purchase orders. The company wants to determine annual requirements for those parts and supplies used in repeat orders so it can ask for bids on those items on an annual basis. After choosing a vendor, the company would put all pertinent information—vendor's name, address, part description, price—and a permissable minimum level into the computer. As soon as inventory reached this level, the computer would generate a purchase order.

• **Production control**—Where production orders are and the time required for each operation will be determined by tying General Time Transacters to the computer net. At every work station, the operator acknowledges completion of an assigned task by putting his employee card, a standard cost card, and a job traveler card into a Transacter; the data are compiled on punched tape which serves as an input to the computers.

Information gathered by the Transacters will also keep more precise tabs on manufacturing costs, and permit cost accountants to detect excessively high fabrication costs at specific work stations.

One big advantage of the computer system is quick preparation of company-wide reports; most can now be issued daily. For example, a critical item report lists all jobs not in process and the reasons for delay (engineering change, lack of raw materials, etc.). This report used to be prepared weekly. Another daily report itemizes the whereabouts of every part or assembly in production. Since Hughes issues over 1,000 engineering changes a week, it is essential that the company locate jobs quickly so that the changes can be incorporated before production progresses too far.

—Mike Murphy
McGraw-Hill News

Letter from Holland

CtE's European editor is back in London after a tour of Dutch industrial installations. He writes his impressions of what's going on in the Netherland's small but bustling instrument and control industry.

In considering what's happening in Holland's instrumentation and control activity, you first have to realize some pertinent facts of geography. The country is a small one, only 13,000 square miles in area; and over 20 percent of that is under water, separated from usable land by the famous Dutch dikes. Until 1950, Holland had been primarily agriculturally oriented. Recognizing the limitation to expansion of the economy because of the shortage of land, the Dutch government instituted a carefully made plan in 1950 to expand the industrial activity. In 10 years, industrial production has grown a whopping $390 million. And Dutch companies spent $25 million for instrumentation and control in 1960, expect to boost expenditures by 25 percent this year.

Last year Dutch firms supplied only $6 to $8 million of the instruments and controls bought for use in Holland. There are four main suppliers: The Phillips organization at Eindhover, Electrofact N.V. of Amersfort, N.V. Hollandse Signaalapparaten (a Phillips subsidiary), and De Witt, both at Hengelo.

• **A broad line**—Phillips' interest in the control field extends broadly. It has recently introduced a new line of controllers, transducers, and miniaturized recorders, and is building up company capability in electronic process control.

The company's tube controller closely follows U.S. design philosophy (for example, it is a live zero system operating between 1-5 ma dc) although it has been designed to fit German standard industrial panels. This year Phillips will introduce a transistorized version with a 5 kc chopper that allows minimum rate and reset times of less than 0.1 sec.

Phillips activity also includes such applications as electronic weighing and dispensing, turbine supervisory equipment, telemetry and reactor controls, and rolling mill load cell controls. Germany is a big customer for much of this hardware. For example, the company has sold an interesting control to the August Thyssen Reversing mill at Duisburg, Germany. In this application, load cells, which check the roll pressure as it squeezes the plates, initiate the drive reversal action when the load cell recognizes that the plate has left the rolls.

• **Military producer**—Probably the biggest producer of military-oriented control hardware is Hollandse Signaalapparaten. The company is building the majority of the controls for the Hawk missile being built in Europe by a consortium. And it is supplying radar controls for the European F-104 production program.

Only about 5 percent of the company's business is outside the military. Signaal supplied the special purpose computer system for the air traffic control setup at Schipol Airport (CtE, April '60, p. 43), and it has done some work on special purpose numerical control of machine tools.

For example, a Signaal built special purpose three dimensional milling machine, designed for the Netherland's Model Ship Basin at Arnhem, mills out model ship propellers to an accuracy better than 0.0004 in., leaving a 100 microin. surface finish. An unusual programming technique reduces the length of input tape required for a typical cutting operation that lasts 8 hours. Input data taken from the drawing at predetermined reference points on a standard grid are fed to a general purpose computer. The machine calculates in another coordinate system the appropriate vertical coordinates for key horizontal locations, putting a sequence of vertical points on a punched tape that serves as input to a director. The director then interpolates between them.

• **Computer-control in steel**—Dutch users of control have done some innovating too. At the Royal Dutch Steel Works in Ijmuiden, an analog computer controls an oxygen-blown converter that turns scrap and pig iron into steel. The computer calculates on-line thermal balances, working in combination with an automatic weighing system that measures the changes of iron.

From the readout of the weighing

ENGINEERING REPORT ON OTHER BENDIX COMPONENT PACKAGES

PRECISION DATA AND CONTROL SYSTEMS FOR LARGE RADAR ANTENNAS

Through intensive research and development for major programs, Bendix offers a wealth of design experience in both digital and analog radar control and data systems. We can:

1 Develop *complete systems or subsystems* to comply with any customer requirement.

2 Provide a wide range of installation options, i.e.: one antenna or a battery; control of one radar by another; digital or analog control. Systems with accuracies of .005° or better can be offered.

Manufacturers of

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RADAR DEVICES • INSTRUMENTATION
PACKAGED COMPONENTS

Eclipse-Pioneer Division

The Bendix Corporation

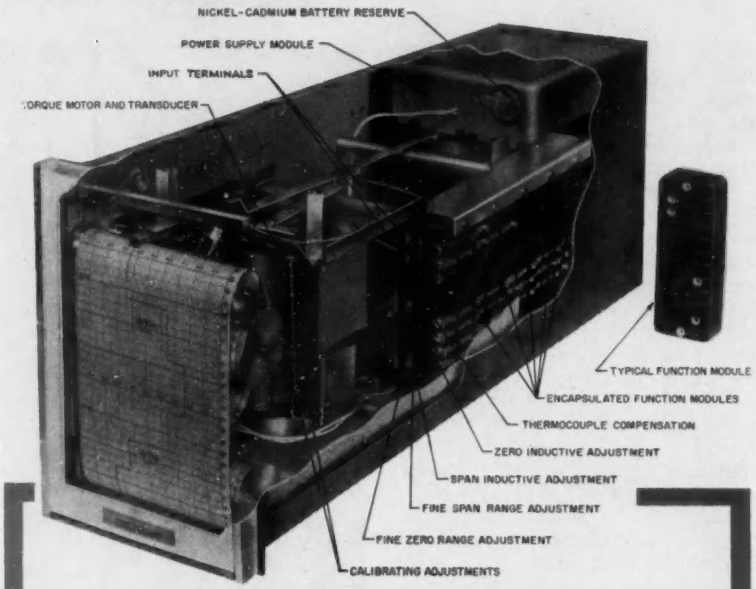
Teterboro, N. J.

CIRCLE 43 ON READER SERVICE CARD

GENERAL KINETICS CONTROL SYSTEMS DE VAR

NEW TRANSISTORIZED MINIATURE RECORDER OFFERS

DC INPUT ISOLATION AND NOISE-FREE DC OUTPUT



The unique DE VAR potentiometer/receiver recorder is particularly suited for Strain-Gage Transducers, Thermocouples and Resistance Bulb Elements. The isolated input circuit rejects high common-mode noise without resorting to input balancing. The DC output signal is sufficiently noise-free to feed data loggers or computers. In addition, a low noise, high frequency carrier signal is available for drift-free operation of controllers and alarms.

- Exclusive inductive zero and span adjustment — continuously variable from 0-5 mv to 0-50 mv.
- Complete solid state circuitry — including unique transistor chopper.
- Battery reserve — eliminates costly down time.
- Full scale rectilinear writing — with 1, 2, or 3 pens.

Our Technical Bulletin R-301 describes the most advanced miniature recorder now available —

Write today

DE VAR SYSTEMS INC.

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GLENBROOK, CONNECTICUT

A DIVISION OF GENERAL KINETICS CORPORATION

LICENSEE IN THE EASTERN HEMISPHERE:
DE VAR LIMITED • LONDON
A MEMBER OF THE ELLIOTT-AUTOMATION GROUP

WHAT'S NEW

system, an operator sets into the analog computer the weight of the charge. Already in the computer as a restraint is the final tapping temperature required. Solving the thermal balance equation, the computer calculates the amount of lime and additive needed for a batch.

• **Blade checkers**—Unilever N.V., world's largest soap and margarine producer, measures the electrical impedance of razor blade packages to determine if the packages have the correct quantity of blades inside. The company found it could not use conventional X-ray or weighing techniques because of variations in the characteristics of the steel. By determining the electrical impedance of a package with a 2 Mc measurement and comparing it against a known package, Unilever can check packages at the rate of three a second. Faulty packages are rejected from the conveyor by a trip gate actuated by a signal from a bridge which is unbalanced by the error signal.

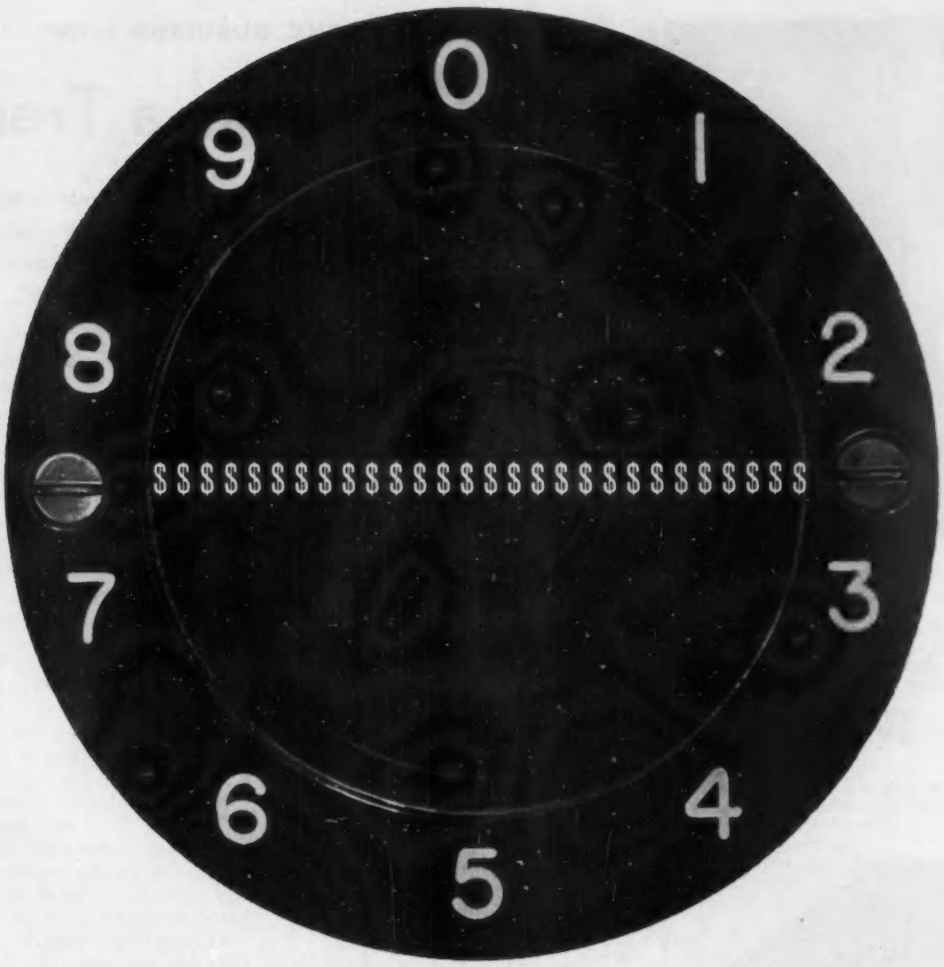
• **For the future**—The Netherlands' future in control is tied closely to the development of young Dutch control engineers. Two sources are turning out the bulk of the control graduates. About 60 engineers majoring in control graduate each year from the Technological University at Delft with the equivalent of a Master's degree. And another 60 steeped in control, come from the Hogere Burgerschools. A newly established technological university at Eindhover will be turning out control specialists too.

—Derek Barlow

New U.K. Computer Control

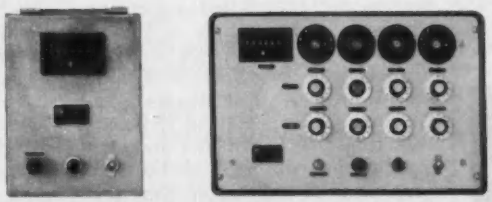
Two British organizations have announced plans for closed-loop control installations with a high degree of automatic operation through general purpose digital computers. Imperial Chemical Industries will run final actuators at a soda plant in Fleetwood Lancaster with a Ferranti Argus process control computer; the Central Electricity Generating Board will install an Argus computer at its new West Thurrock (Essex) generating plant for automatic startup and shutdown of a 200 Mw boiler.

At the ICI installation, the computer will replace 100 analog controllers. The power plant application was prompted by the large number of manipulations that have to be repeated. Eight hundred controls have to be manipulated in a six hour period every time the boiler goes on line.



What price Automation? Veeder-Root's electronic answer will surprise you! Now you can buy automatic electronic counting and controlling functions on a "tailored to fit" basis. Just what you need to step up efficiency and cut costs. No more!! No less!! Start with what you want to count... next determine the fastest counting speed you need... then consider how you could automate your equipment by triggering one or more of its operations electrically.

With these basic facts, your Veeder-Root sales engineer can tell you which electronic counters will meet your automation requirements most economically. These compact units can count up to 300,000 times per minute. They can sense objects the size of a pinhead. Control types are easily preset to start, stop and regulate your equipment... and accurately coordinate its production. Find out how little it costs to build automation into your production setup. Write to Electronic Controls Division, Veeder-Root Inc., Danvers, Mass. **count on...Veeder-Root**



The Veeder-Root electronic counter line ranges from the 1697 Count-Pak for counting to 2500 cpm at a unit cost of approximately $100 . . . to the highly versatile 1804 series for counting up to 300,000 cpm and controlling any number of operations.

CIRCLE 45 ON READER SERVICE CARD

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CANCO
RCA
NASA
Judging by the Company We Keep...
Electro-Mech

Electro-Mech Corporation expands to better serve the increasing "Company We Keep." We now have representatives in the major industrial areas of the United States. From Coast to Coast we stand ready to solve your control system problems.

"MEANWHILE BACK AT THE HOME OFFICE"—we also have expanded.

Pictured below is our new modern, 24,000 square feet, plant at 500 Livingston Street, Norwood, New Jersey.

Within—the most modern production, engineering, and test facilities are producing control systems and control centers of the highest quality. No detail is overlooked in providing the most thoroughly-engineered and tested control systems.

Regardless of your location, Electro-Mech Corporation is at your call. Allow us to "modernize" your instrumentation. Consult Electro-Mech on all your future control systems.

Electro-Mech Corp., Norwood, N. J.

Electro-Mech

Control Bucks a Trend

Business has been spotty; unemployment up; auto sales down; steel production down; but control makers haven't suffered as other sectors of the economy. Most control companies are still enjoying good business and good prospects for 1961.

NEW YORK—While the newspaper headlines reported new unemployment highs—3,289,000 workers drew unemployment benefits in the first week of 1961, a weeklong layoff in most auto plants in February because of overproduction, and steel production hovering down around the fifty percent of capacity mark, the U. S. Dept. of Commerce was able last month to predict continued growth in instrumentation and control sales. The Department's annual forecast (prepared by the Business and Defense Services Administration, Scientific, Motion Picture, and Photographic Products Div.) estimated 1961 sales of scientific and industrial instruments will increase *substantially* over the $4.5 billion estimated sold in 1960.

Taking a close look at what's happening, Dept. of Commerce forecasters found several reasons why the control industry has been bucking the U. S. economy's downward trend.

▶ Item. The proportion spent for plant modernization is expected to rise to 80 percent of capital expenditures in 1961 from 61 percent in 1960. Much of this modernization is going for new automatic equipment requiring extensive control.

▶ Item. Industries where automation is increasing fastest—such as chemical, petroleum, food and beverage, and public utility—will spend more in 1961 than in 1960 for plant expansion and modernization. Such spending may rise as much as $3 billion to $20 billion.

▶ Item. The ratio of instrument-to-equipment cost, a traditional 6-percent average in process control, is rising as on-stream analysis and control devices and computer-controlled process systems are added to plants.

▶ Item. Expenditures for additional research and development facilities will rise in 1961. Federal sums spent this way will increase about 15 percent over 1960's $450 million; industrial spending for new R&D facilities will jump to $800 million, up almost 20 percent over 1960's total of $680 million.

▶ Item. Federal spending for commercial air traffic aids will total about $165 million, $47 million more than was spent last year.

In the first quarter of 1961, this rosy estimate was supported by some cheering sales figures and production plans. Process control companies like Minneapolis-Honeywell and Foxboro were enjoying "satisfactory" sales, computer sales continued rising, stimulated by the introduction of new machines like the Burroughs 5000 and Univac's 1107, and the electronic component industry was chalking up sales at a rate that guaranteed another record sales year in 1961.

Production expansion plans came from General Electric in Phoenix, which announced it would double its computer production space by adding 100,000 sq ft of manufacturing area and would increase its personnel by 30 percent, adding another 500. RCA will add 10,000 sq ft to its Natick, Mass., computer plant.

• **Component picture** – A bright 1961 for semiconductor device manufacturers is forecast by GE vice-president L. Berkley Davis. Eyeing last year's sales and this year's prospects, Davis predicts factory sales of electronic tubes will total $827 million in 1961—about the same as 1960. But sales of semiconductor devices should reach $626 million in 1961, almost a 20-percent gain over 1960.

One of the biggest areas of growth, says Davis, is transistor sales. He expects the industry will sell 180 million transistors in 1961, a gain of 38 percent over 1960, representing $380 million worth of business. Solid state rectifier sales should grow by 16 percent to $136 million.

• **Share of military**–Control makers share of the military budget is likely to stay as good as last year despite additional cutbacks in military aircraft. The slump resulting from decreased military aircraft sales is likely to be picked up by additional civilian aircraft sales and increases in missile spending. Missile spending should roll along at a rate of at least $3.7 billion. Military and civilian aircraft sales should total almost $8 billion, about the same as in 1960. And mili-

NEW HIGH FLOW SERVOVALVE

by MOOG: INDUSTRIAL DIVISION

***SERIES 72**

These servovalves are normally used in closed loop position, velocity and force systems to provide precise fast response control at high power levels. Designed specifically for industrial use, the Series 72 servovalves embody ten years of MOOG experience as the leading supplier of two-stage servovalves.

FEATURES:

- INTERNAL MECHANICAL FEEDBACK . . . provides high spool driving force with attendant performance and reliability advantages.
- RUGGED FORGED STEEL BODY . . . designed to perform in the industrial environment.
- REPLACEABLE PILOT STAGE FILTER . . . affords added protection and permits field servicing.
- SEPARATE PILOT SUPPLY PORT (Optional) . . . offers greater flexibility in design of hydraulic power system.
- COMPLETELY SYMMETRICAL DESIGN . . . minimizes null shift with pressure and temperature.
- AVAILABLE FROM STOCK . . . in flow ratings of 25, 40 and 60 GPM pressure.

MOOG SERVOCONTROLS, INC. INDUSTRIAL DIVISION EAST AURORA, N. Y.

how North Atlantic's instrument servos fill the five major systems jobs . . . exactly.

Measurement, remote display, data conversion, control, computation . . . Name the task and it's probable that the North Atlantic man can show you how to meet it precisely from NAI's comprehensive line of 3" and 2" vacuum tube and all solid state instrument servos.

Production models are available for high- and low-level ac, dc, synchro, strain gage, thermocouple, resistance bulb and other inputs. Most can be supplied with choice of pointer, counter, torque shaft or digitizer outputs. All utilize flexible design that permits any combination of input-output features to be supplied rapidly to user requirements, for both ground and airborne applications. Some are described below.

SBI-201
Single Pointer DC Ratiometer

Input
Denom. 5-50v
Num. 10 mv-100v
Accuracy
±.2 to ±.5% fs
Resolution
.1 to .2%
Response
.25 sec. fs

SBI-401
A-to D Converter

Input
10 mv to 100v dc
Accuracy
±.1% fs
Resolution
from 0.05%*
Response
from 2 sec fs*
*depending on encoder used

SBI-501
Shaft Position Repeater

Input
ac, dc or synchro
Accuracy
±.1 to ±.5% fs
Resolution
.05 to .25%
Response
7 sec. @ 15 oz-in

SBI-502
Three-Digit Counter Readout

Input
ac, dc, or synchro
Accuracy
±0.5 to .1% fs
Resolution
.02 to .05%
Response
15 sec. fs

SBI-503
Dual Scale Readout

Input
ac, dc, or synchro
Accuracy
.05 to .1% fs
Resolution
.02 to .05%
Response
6 sec. fs

If there's a critical job for an instrument servo in your system design, it will be worth your while to talk to your North Atlantic engineering representative. For his name, call or write today. Or request Catalog SFC-1 for complete data.

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TERMINAL DRIVE, PLAINVIEW, L. I., NEW YORK • OVerbrook 1-8600
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WHAT'S NEW

tary spending will be buttressed by the burgeoning space program.

Forecasts are not so sure nor so optimistic in one other area of control: industrial electrical control. Here the picture has been clouded by the recent sweeping successful antitrust actions brought by the Federal government against leading electrical manufacturers. Chief complaint: price fixing and market assignment in a variety of products ranging from giant turbine generators to controls. Most veterans in the electrical control industry feel that the court's decisions will upset the traditional marketing practices of the industry.

But at least one marketing man feels differently. He told CtE, "This means a new deal for control makers. The manufacturer with the most aggressive sales force and the best product now has a chance to get the share of business he deserves. He doesn't have to be satisfied with the segment dealt him by a cartel."

Many industry observers are asking "How long can the control industry maintain its spectacular growth"—an annual growth averaging 11 percent, according to the Dept. of Commerce. The feeling is that as long as industry is concerned with increasing productivity through improved mechanization, control suppliers will enjoy a high level of business.

GE Sets Sights On Systems With Management Shifts

Long a model of the diversified corporation with virtually autonomous divisions, General Electric Co. has acted to remove the crimp this arrangement tends to put in sales of systems engineering jobs. In two organizational changes calculated to increase GE's share of the highly competitive–and lucrative–control systems business, the company amalgamated into one group all its market development and advanced engineering activities for industrial control, and the next day GE's Computer Dept. announced that management of its industrial process control computer business had been transferred to the Industry Control Dept.

What this means is that GE will now have control systems salesmen able to sell complete engineering programs. Included in the responsibility of this new Systems Sales and Engineering Operation will be data processing, mathematical simulation, control and instrumentation engineering,

(*Continued on page 202*)

SINGER* NUMERICAL CONTROL

The Singer Numerical Control System represents the most direct approach to point-to-point positioning yet conceived. It offers simplicity, reliability and economy, reducing costs of maintenance, labor and downtime.

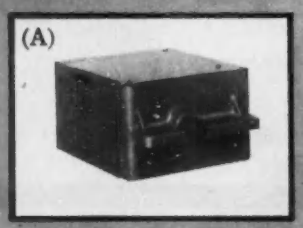
A major feature of Singer automation is modular design. This makes it possible to assemble basic units in a variety of control systems.

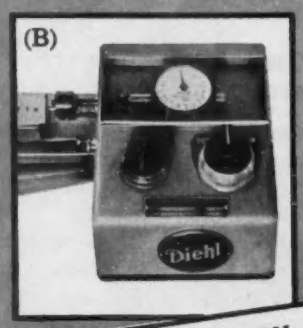
AUTOMATIC POSITIONING SYSTEM

For example, because of the simplicity of Singer modular design, an Automatic Positioning System can be furnished immediately as standard for use on a drilling machine to drive and position the work table and saddle motion.

All that is required is a motor drive assembly (A) and a position indicator control (B) on each axis. This system will then operate with standard end measures.

At any future time, tape control can easily be added to provide a complete Singer Numerical Control System, as shown below with a Fosdick 5BM Sensitive Drill Press.





AN INVITATION

You are cordially invited to visit the Singer Numerical Control demonstration room at the Diehl Manufacturing Company

Diehl†

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SUBSIDIARY OF THE SINGER MANUFACTURING COMPANY

Finderne Plant, Somerville, New Jersey

Telephone: Randolph 5-2200

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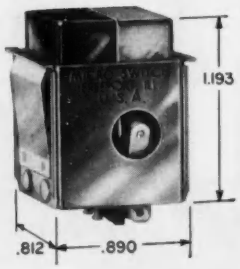
MICRO SWITCH Precision Switches

FULL COMMAND IN ONE CUBIC INCH!



NEW MINIATURIZED LIGHTED PUSH-BUTTON SWITCHES SAVE PANEL SPACE

The new "302PB" Series combines control and visual indication in one completely assembled unit that requires less than one cubic inch of panel space. These miniaturized lighted push-button assemblies can be mounted or removed without tools.

The display screen, mounting flanges and two single-pole double-throw basic switches are all integral components, permanently assembled to make a mechanically strong unit built for long life. Fifteen display screen color combinations are available, obtained by use of a split screen. A separate miniature lamp illuminates each half of the screen. These lamps are designed for infinite service life. "302PB" Series switches conform to the applicable requirements of MIL-S-6743, MIL-S-6744 and MIL-E-5272A. Check the nearby MICRO SWITCH Branch Office, listed in the Yellow Pages for full information or write for Data Sheet 182.

MICRO SWITCH . . . FREEPORT, ILLINOIS
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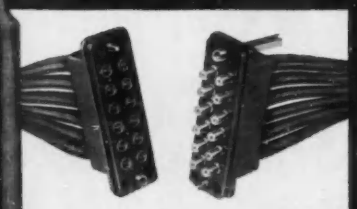
MICRO SWITCH Precision Switches

50 **CIRCLE 50 ON READER SERVICE CARD**

COAX HYFEN® CONTACTS

reliable solderless contacts result in dramatic reduction of installation time

wide application—all with snap-locked removable contacts



Type MB-X

Coax in miniature rectangular configurations.

AQUALOK™

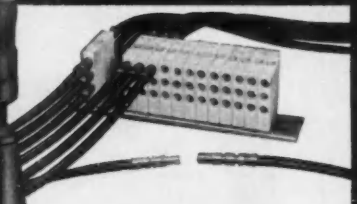
Weather-sealed round connector—either all coax or in combination with single conductors.

Coax Bantam HYFEN

Connectors for standard and miniature coax—either all coax or in combination with single conductors.

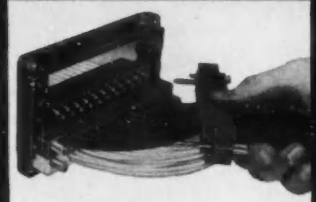
Coax Feed-Thru

Miniature and standard connector (above) and splice (below). All plastic shells — lightweight, durable, impact resistant.



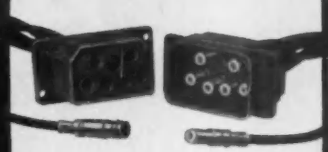
Coax MODULOK®

Modular terminal block with spring-loaded removable contacts.



Type PD-X

Modular HYFEN inserts for all standard or miniature coax or in combination with inserts for single conductors.



Type ME-X

Rack and panel HYFEN series—features one piece shell, one piece inserts.

Burndy's coax contacts, for both miniature and standard coax cable—feature crimped inner and outer contacts, which provide a more reliable connection, faster and easier. High speed production tooling results in low installed cost—crimps contacts in any circumferential position. Few parts simplify installation. No heat to damage insulation.

For further information write OMATON DIVISION

BURNDY

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See more at IRE Booths 1735-1737

CIRCLE 51 ON READER SERVICE CARD

Here's 0.1° Sensitivity at a Competitive Price!

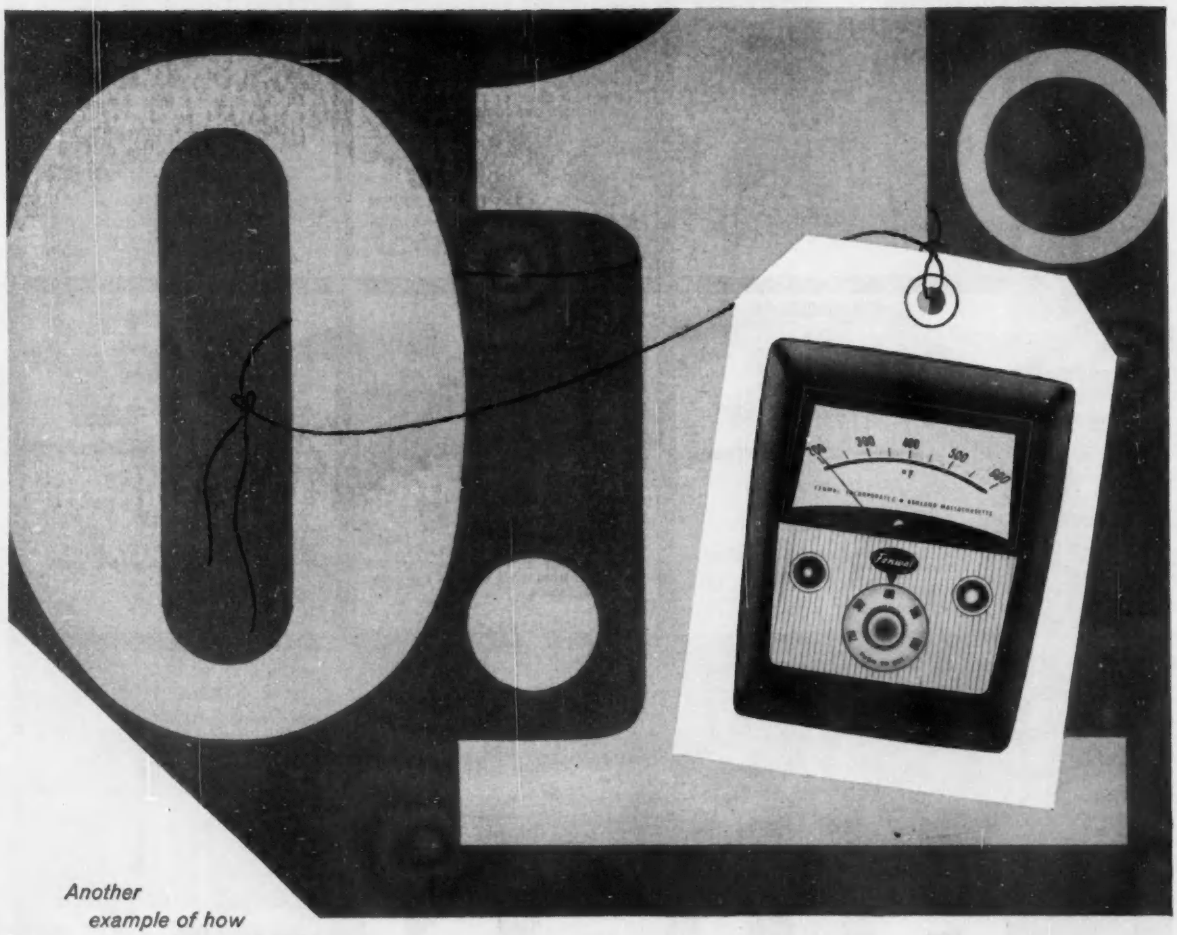
... Fenwal's New "561" Temperature Controller

The new "561" indicating controller responds to temperature changes of 0.1° or less! And is yours at a competitive price! These two features alone make it an instrument you should investigate... but there's more!

You can choose from five standard temperature ranges . . . within the span of −50 to 600°F. Furthermore, scales start and end within *your* ranges, permitting larger graduations, better legibility, easier readout. And control and indication are separate but simultaneous. *Should your indication fail the "561" will continue to control with complete accuracy.*

This precise instrument gives unvarying performance. Its indication and control will not vary with fluctuations of input voltage nor changes in ambient temperature. It offers the option of either ON-OFF or proportional control . . . has 10 AMP/120 VAC relay capacity. Smartly styled to complement modern industrial machines and interiors, *the "561" offers you all these extras at a competitive price.*

A Fenwal engineer will be glad to supply information on the "561", or any other temperature control in Fenwal's broad line. Write Fenwal Incorporated, 293 Pleasant Street, Ashland, Massachusetts.



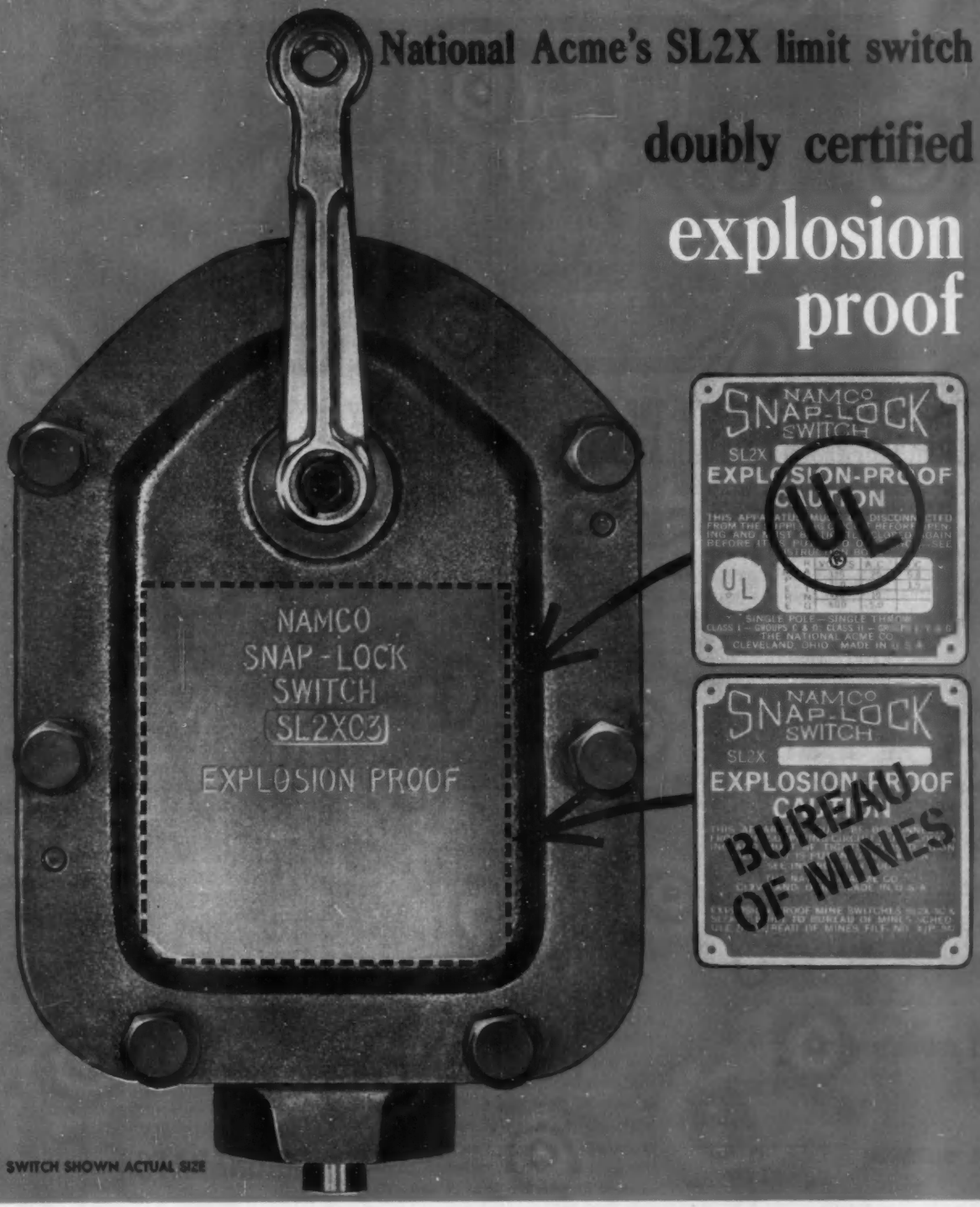
Another example of how

Fenwal CONTROLS TEMPERATURE . . . PRECISELY

National Acme's SL2X limit switch

doubly certified

explosion proof



SWITCH SHOWN ACTUAL SIZE

Specify National Acme's SL2X . . . and eliminate limit switching problems under explosive conditions. Tested and certified "explosion-proof" by both Underwriters' Laboratories and the Bureau of Mines, the SL2X is specifically designed for use in the mining, chemical, process industries . . . anywhere explosions cannot be tolerated. Latest of National Acme's dependable SL2 "Machine Life" Limit Switches, the SL2X also offers . . . a variety of cam arrangements for extreme operating flexibility . . . ample overtravel (67°) and by-pass (90°) . . . light operating pressure (12½ lbs. at 1½" radius). Get all the details on this new standard of limit switching dependability and safety. Call, write or wire.

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165 E. 131st STREET
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Sales Offices: Newark 2, N. J., Chicago 6, Ill., Detroit 27, Mich.

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FISCHER & PORTER

ONLY COMPLETE FLOWMETER HOUSE

THE HANDIEST GUIDE TO THE VARIOUS AND SUNDRY METHODS PRESENTLY AVAILABLE FOR MEASURING FLOW

It has been our pleasure and profit over the years to aid and assist divers engineers in the estimable task of selecting the one—nay, the *only* device best suited to measuring a given flow. But truly, the years have added, the devices have multiplied, and the task of selection has grown ever more complex. As a result, the "handy" guides, so reminiscent of an earlier day have grown less handy all the time. Let us see how handy we can be.

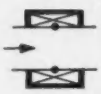
LESSON I

There are but four major types of flowmeters.

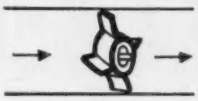
1. VARIABLE-AREA

2. VARIABLE HEAD

3. OBSTRUCTIONLESS



4. INTEGRATING



LESSON II

In order to be as handy as possible, we shall limit our discussion of the advantages of the four basic types to a single characteristic benefit.

1. Variable-Area: linear scale
2. Variable Head: flexibility
3. Obstructionless: obstructionless
4. Integrating: accuracy

LESSON III

This lesson is of the most importance as it concerns the various factors necessarily involved in the judicious selection of flowmetering devices. These primary and critical factors are: fluid property limitations, application, installation and economics. We need not go into detail on these factors since our Bulletin 91-119, a veritable gem of condensation, reviews all of these factors in the short space of only six pages. There is a limit as to how short and "handy" such a guide can be.

If you are one of those, and there are many, who philosophically opposes all "handy" guides, then we need only remind you that we make all of the four major types. Indeed, we are the only company to do so. We also wish to state that we use a wide variety of materials to construct these meters including many readout and process control devices. Our laboratories include the finest and most advanced flow measuring and calibrating equipment. A call to our field engineers can save you trouble and bring you a firm recommendation unencumbered by bias or prejudice.

TO THE RIGHT

is a sampling of some outstanding examples of each type of meter in our flowmetering line.

{ Variable-Area Flowmeters }

Fischer & Porter has indeed made its mark in lands far and wide as the leading manufactory of variable area meters, finding itself pleasantly faced with such wide acclaim for ease of use and simplicity that it defies description. Yea, and to no surprise. Indeed our people have labored unceasingly to INTRODUCE EVERY MAJOR ADVANCE in this noble form of flowmetering, to wit: the glass tube that allows viewing the rate of flow directly; the bead-guide and Tri-Flat meter for matchless float stability; the predictable float which simplifies calculations; the metal tube for high pressures and temperatures.

Frictionless! Foolproof!

—herald the fortunate employers of the MAGNABOND coupling developed by Fischer & Porter for detecting the linear motion of the float, with abundant power to operate a multitude of accessories for recording, transmitting, totalizing and controlling. The ingenious detection system employs permanent magnets sealed into a non-magnetic, corrosion-resistant extension unit, and is widely used in conjunction with the popular FLOWRATOR meters.

The NEW, ALL NEW

MAGNARATOR

with

FLOW INDICATOR

and

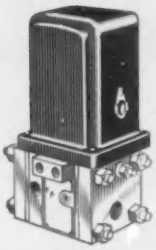
PNEUMATIC TRANSMISSION

This amazing apparatus is distinguished as the TRUE in-line, through-flow meter. Of great joy to installation and maintenance men alike, no extension is needed and there are no

crooks, crannies or corners where material can collect. The MAGNARATOR, kin to the extension-type MAGNABOND flow transmitter, is lofted to great heights of applicability by a new magnetic coupling principle. It measures, indicates and transmits pneumatically with a linear output signal!

Variable Head Flowmeters

...featuring the



DP TRANSMITTER

by the wizards of Warminster

FISCHER & PORTER

Outwits PULSATION!
Outwits CORROSIVE FLUIDS!
Outwits STEAM TRACING PROBLEMS!

This popular differential pressure transmitter undeniably supports its claim as being the best in the world. Since it was first presented to the metering public its success has been remarkable. WHY? Its superiority over all others is substantiated by the FACTS OF ACTUAL USE!

ASTOUNDING ADVANTAGES
found in no like instrument

ADJUSTABLE DAMPING in the differential sensing system, Gentlemen, which is where it should be. We warrant there to be no other method that lets you measure PULSATING flow without zero shift, PHANTOM signals, diaphragm fatigue or premature parts failure.

NEW METALS & ALLOYS such as Tantalum, 316 Stainless and Monel are STANDARD materials of construction for the sealing DIAPHRAGMS. Other "wetted" parts are fabricated from 316 Stainless, Monel, Nickel and Hastelloy C—as you desire. A perfectly sealed measuring chamber filled with the celebrated silicone oil PROTECTS ALL WORKING PARTS.

INTEGRAL STEAM TRACED PROCESS FLANGES, available from our shipping shelves, enables one to conveniently heat process connections to prevent fluids from "freezing"—all without TROUBLESOME AND EXPENSIVE lagging and tracing in the field.

Obstructionless Flowmeters

THE JUSTLY CELEBRATED MAGNETIC FLOWMETER

OF FISCHER & PORTER
one of the very best instruments ever invented

An unobstructed length of pipe that accurately measures the flow of even the least conductive fluids by the Invisible MAGNETIC FIELD. Extends the range of accurate flowmetering to heretofore unbelievable limits. A rangeability of 3000:1! Measures the flow of any liquid with a conductivity of no less than 0.1 micromho per centimeter.

Measures flow IN EITHER DIRECTION and without auxiliary equipment. Handily provides full scale recording of ANY FLOW RATE from 1 to 30 feet per second at the TURN OF A DIAL.

Coupled with a

Fully Transistorized Recorder

Years ahead of its time! An instrument of the future which you can profitably use today. The new recorder incorporates compact transistorized circuits which have reduced space requirements incredibly. Now the entire instrument is contained in a SINGLE DEPTH CASE. No black boxes to add. All amplifiers are mounted on plug-in cards.

Gentlemen, the Magnetic Flowmeter itself represents the GREATEST ADVANCE in flowmetering in the last quarter century!

YOUR ATTENTION INVITED!

Integrating Flowmeters

TURBINE METER

Here is the zenith in flowmetering of the greatest accuracy over a wide range, designed for the most fastidious users. Each and every revolution of the bladed rotor in the TURBINE METER signifies the passage of a definite unit of fluid volume with an ELECTRICAL pulse. The total number of counts is proportional to the total volume of FLUID PASSING THROUGH the meter.

NEW ! NEW ! NEW

TRANSISTORIZED
READOUT DEVICES

The Turbine Meter can be linked with any of an unbelievable number of Readout Devices to oversee your process operations. Exemplary devices, utilizing the most up-to-date transistorized electronic components and techniques can indicate, totalize, record and control.

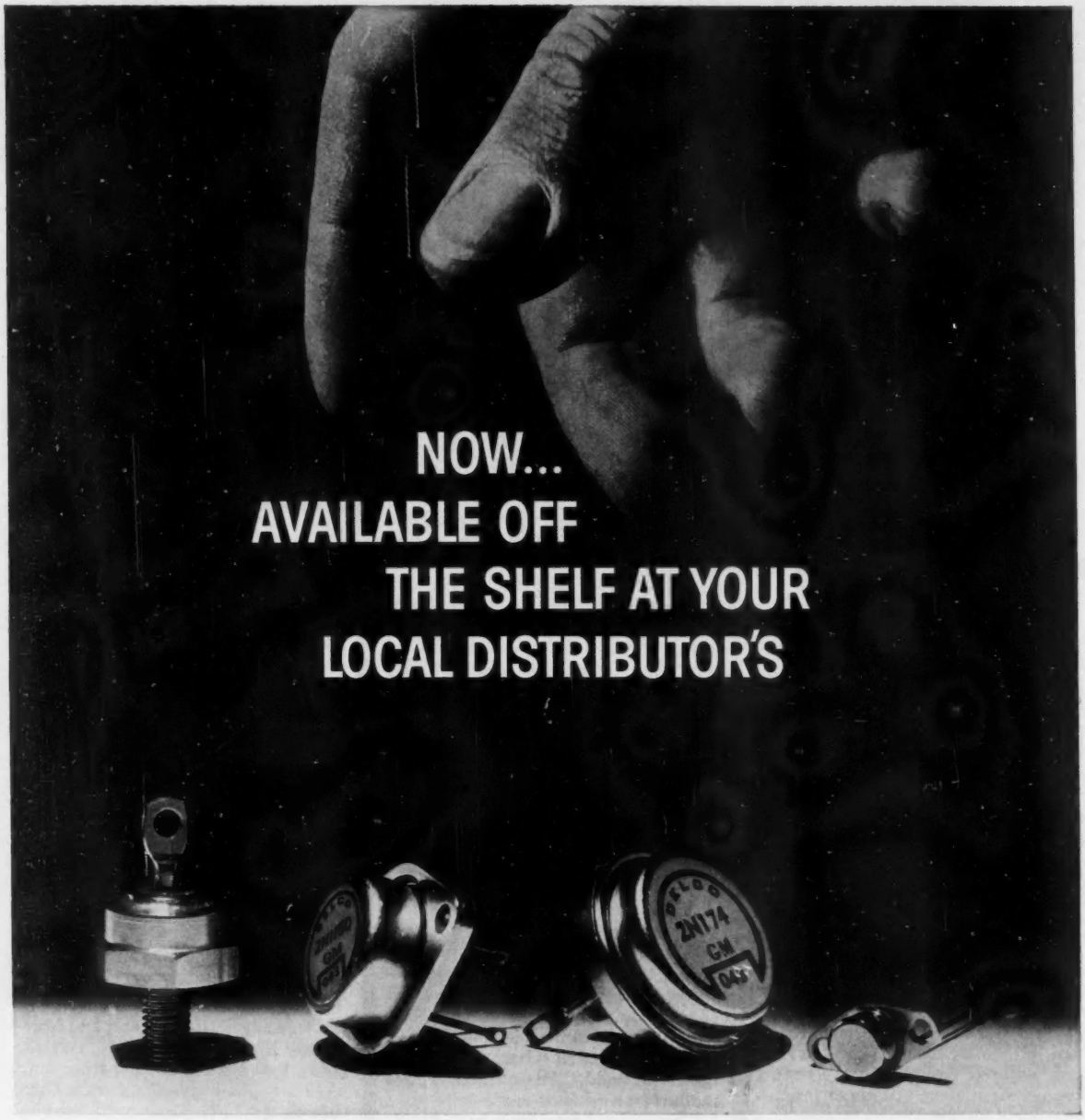
Continuous In-Line Blending
NOW A FACT

Triumph at last. To the marriage of the amazing Turbine Meter and Marvelous Electronic Readout Devices goes a new distinction. Together they have brought to reality a truly Continuous IN-LINE BLENDING System for blending of two or more fluids. This combination offers to you many other solutions for conquering DIFFICULT & DEMANDING & COSTLY flowmetering operations.

STATE YOUR PLEASURE, GENTLEMEN!

To better acquaint our public with the BENEFITS and ADVANTAGES of our UNIQUE products we have caused to be printed handsome booklets for the general edification. We will gladly post to you a selection of these works upon your application. It will only require an expression as to the type of meter(s) of interest, that is Variable-Area, Variable Head, Obstructionless and Integrating and also our "handy" Guide (91-119). We are your obedient servants in this as in all other matters.

FISCHER & PORTER CO.
WARMINSTER, PENNSYLVANIA & TORONTO, CANADA
A world-wide INSTRUMENT COMPANY with plants in Australia, England, France, Germany, Holland, Mexico, as well as the U.S.A.



Delco Radio's complete line of semiconductors is now available at your local distributor's. You can get fast off-the-shelf service on military and industrial transistors for high and low voltage switching and power supplies, for low-leakage DC amplifiers and for audio amplification. Your distributor has Delco silicon power rectifiers, too. The distributor nearest you has a complete catalog of application-proved semiconductors.

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NEW FROM POLARAD—
UNIVERSAL SERVO ANALYZER

MEASUREMENT	METHOD OF MEASUREMENT	INPUT TO SERVO SYSTEM	APPLIED TO SCOPE'S VERTICAL PLATES	APPLIED TO SCOPE'S HORIZONTAL PLATES	RESULTING SCOPE PATTERN Typical Response	RESULTING SCOPE PATTERN 0° Phase Shift
PHASE RESPONSE OF A-C SERVO SYSTEMS	Bowtie	50 cps to 6000 cps carrier, modulated at rate of 0.001 cps to 100 cps.	Modulated Return Signal	Low-Frequency Sine Wave		
	Carrier Lissajous	50 cps to 6000 cps carrier, modulated at rate of 0.001 cps to 100 cps.	Modulated Return Signal	Carrier Reference Envelope		
	Sweep	50 cps to 6000 cps carrier, modulated at rate of 0.001 cps to 100 cps.	Modulated Return Signal	Linear Sweep	Fig. 5-a	Fig. 5-b
	Sweep	50 cps to 6000 cps carrier, modulated at rate of 0.001 cps to 100 cps.	Demodulated Return Signal	Linear Sweep	Fig. 5-c	Fig. 5-d
	Lissajous	50 cps to 6000 cps carrier, modulated at rate of 0.001 cps to 100 cps.	Demodulated Return Signal	Low-Frequency Sine Wave		
PHASE RESPONSE OF D-C SERVO SYSTEMS	Bowtie	Low-Frequency Sine Wave 0.001 cps to 100 cps	Sine Wave Return Signal	15-kc Reference Envelope		
	Carrier Lissajous	Low-Frequency Sine Wave 0.001 cps to 100 cps	Modulated Wave Return Signal	Carrier Reference Envelope		
TRANSIENT RESPONSE OF A-C SERVOS	Analysis of Returned Square Wave, Triangular Wave, Ramp, or Impulse Functions	Function with Carrier	Modulated or Unmodulated Return Signal	Linear Sweep	Square Wave Ramp	Triangular Impulse
TRANSIENT RESPONSE OF D-C SERVOS	Analysis of Returned Square Wave, Triangular Wave, Ramp, or Impulse Functions	Function without Carrier	Modulated or Unmodulated Return Signal	Linear Sweep	Square Wave Ramp	Triangular Impulse
FREQUENCY RESPONSE OF A-C SERVOS	Oscilloscope Calibration	50 cps to 6000 cps Modulated Carrier	Modulated Return Signal	Linear Sweep (if desired)		
FREQUENCY RESPONSE OF D-C SERVOS	Oscilloscope Calibration	Low-Frequency Sine Wave	Modulated Return Signal	Linear Sweep (if desired)		

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MODEL SV-1 SERVO ANALYZER

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The new Polarad MODEL SV-1 SERVO ANALYZER is a complete instrument for testing AC and DC servo mechanisms in all applications. It combines a multiple precision signal generator and oscilloscope. Internally generated reference signals are compared with servo outputs and are displayed visually for quick servo analysis.

FREE LIFETIME SERVICE

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Representatives in principal cities.

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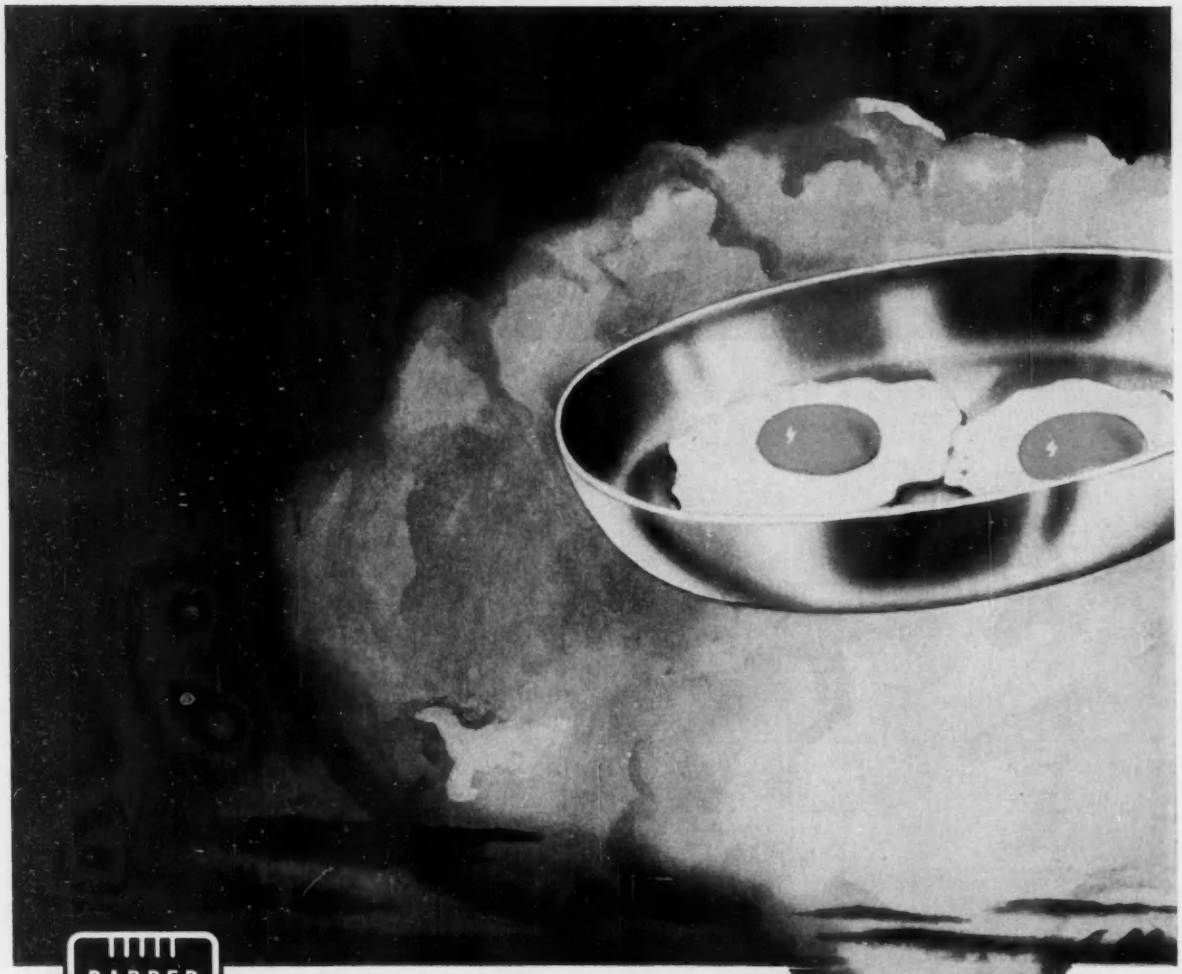
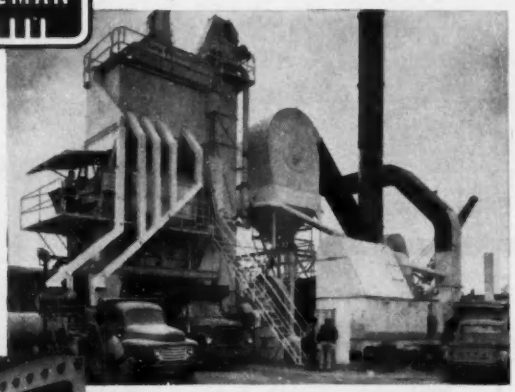


BARBER COLMAN

Automatic



A top-grade, more workable asphalt mix has uniform conditions maintained for every batch with a process control system designed by Barber-Colman. Result: savings in labor, time and material at giant, new mixer rated to 175 tons per hour.

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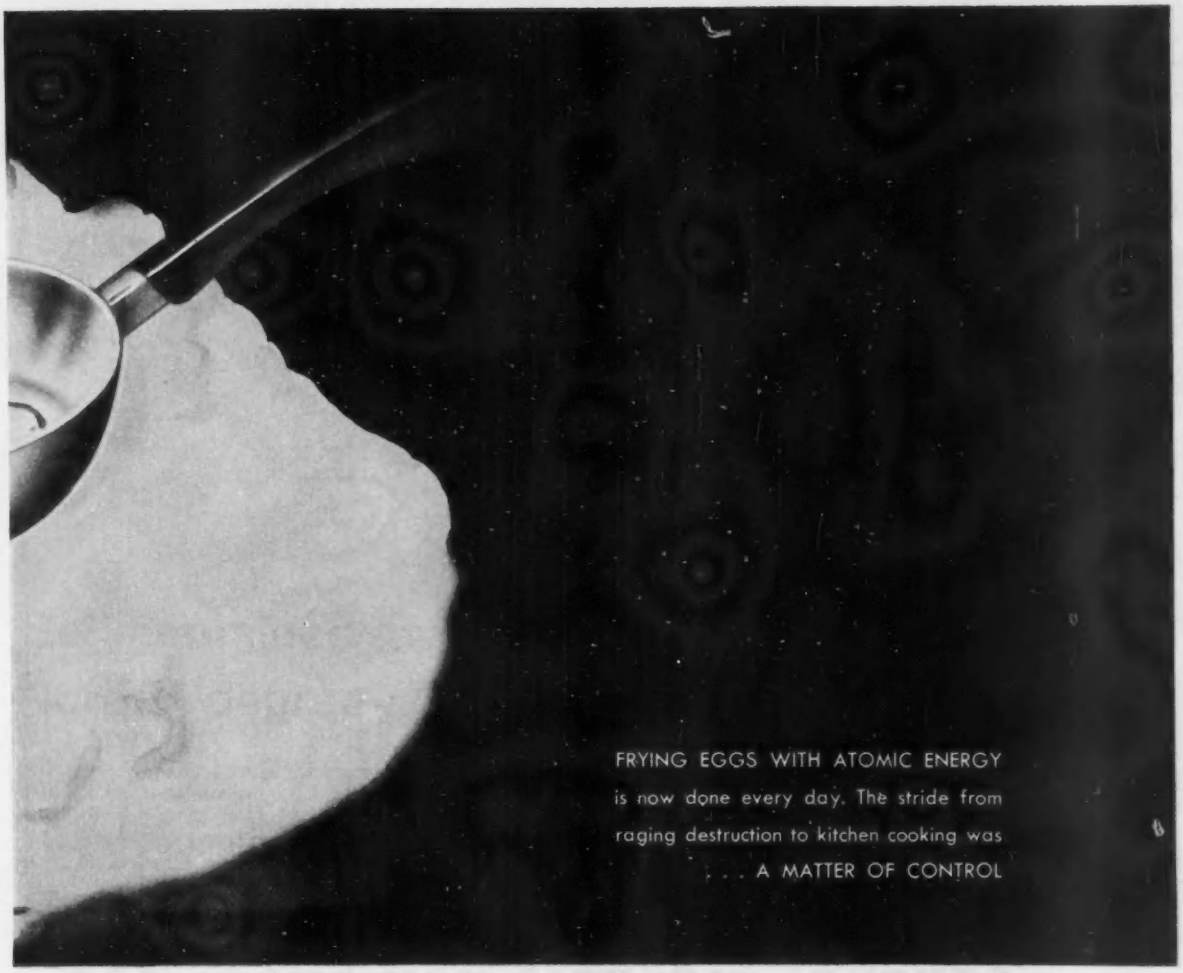
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is now done every day. The stride from
raging destruction to kitchen cooking was
. . . A MATTER OF CONTROL

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. . . are a business matter with Barber-Colman, Wheelco Industrial Instruments Division. Your process can be precisely and profitably controlled by superb instruments installed by engineers who know both instrumentation and process needs. Drawing on a twenty-five year background, the Barber-Colman engineer helps you select components from the thousands of instruments available, plans your control system, and insures proper installation. Call on him now.

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- AND MANY OTHERS

GENERAL ELECTRIC USN 2N681-688 SILICON CONTROLLED RECTIFIERS NOW MEET MIL-S-19500/108

The first SCR to meet MIL-S-19500/108 is now available in production quantities from General Electric. This is natural. G.E. originally developed the SCR, now offers a wide range of current ratings including the new C8, 1.3 amp and C55, 70 amp types. General Electric provides much of the know-how and ideas on how to apply the SCR... brought in reduced prices based on large volume production... and has reams of reliability and test data, the kind you should know about.

The G-E SCR is changing a lot of old ideas about power control and switching, in terms of circuit design *and* cost. Can you afford to wait any longer? Call your G-E Semiconductor District Sales Manager today. He'll give you all the help you need.

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For fast delivery at factory-low prices see your local G-E Distributor.

GENERAL ELECTRIC

Self-contained logic:
Norden degree-counting binary decimal encoders

Encoders in this group offer unique self-selecting V-brush system, developed by Norden engineers, to prevent ambiguity without external brush-selection circuitry. Consequent reduction in associated equipment encourages miniaturization in system design. The unit weighing only 13.2 oz.—the Model ADC-5-36BCD—translates shaft position into degrees to a resolution of 0.01°. Converters are available with both standard 8-4-2-1 and 4-2-2-1 codes.

FIVE OF NORDEN'S STANDARD DEGREE-COUNTING BINARY DECIMAL SHAFT ENCODERS:

MODEL	ADC-ST3-36BCD	ADC-3-36BCD	ADC-4-36BCD	ADC-5-36BCD	ADC-6-36BCD
Total count	360	360	3,600	36,000	360,000
Revolutions for full count	1	3.6	36	360	3,600
Accuracy—1 part in:	360	360	3,600	36,000	360,000
Mounting	Size 33	Size 23	Size 23	Size 23	Size 23

APPLICATIONS: gun turrets, antenna pattern recorders, airborne data acquisition, navigation systems, shipboard computers . . . elevation and servo azimuths, machine tool positioning tables.

SIMPLIFIED DESIGN PLUS QUALITY PRODUCTION ACHIEVE UNEXCELLED RELIABILITY

- Reduced number of components minimizes possibility of error.
- Meets Military Specifications MIL-E-5272A and MIL-E-5422D.
- Self-checking gating devices provide virtually 100% error monitoring.
- Two brushes parallel for each contact reduce noise.
- Precious metal brushes are mated to micro-finish pattern disc during run-in.
- Precision design and manufacture achieve longer life: 4×10^6 revolutions at 150 RPM under continuous full load.

RELIABILITY IS DESIGNED IN . . . AND BUILT IN BY UNUSUAL MANUFACTURING CONDITIONS

Scientists and military electronics experts testify to Norden's unusual quality control techniques. Encoder parts are manufactured, assembled, inspected and reinspected with extreme care in positive-pressure, dust-free, temperature-controlled laboratories. Norden's exceptional design and production facilities are the foundation of encoder reliability. Detailed manufacturing control specifications are available for your inspection.

Review your requirements and send for complete specifications on these or any other Norden encoders. Write, or call Norwalk, Connecticut, TEmple 8-4471.

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America's dramatic accomplishments in space technology are made possible not only by developments in science, but by advances in technical management concepts. A new type of generalist has emerged to meet the demands of systems engineering and technical direction of complex missile and space projects. This technical manager combines a broad knowledge of science and engineering with the leadership capability to fuse the disciplines of creative specialists into a dynamic, effective team ● In its six years as a principal contractor for the Air Force, NASA, and ARPA, STL's hard core of technical management generalists has set the pace in developing new members of this very scarce breed ● Their unique ability is the prime asset in Space Technology Leadership ● Scientists and engineers who would add this new management dimension to their professional careers are invited to submit their resumes to STL, where they will receive meticulous attention.

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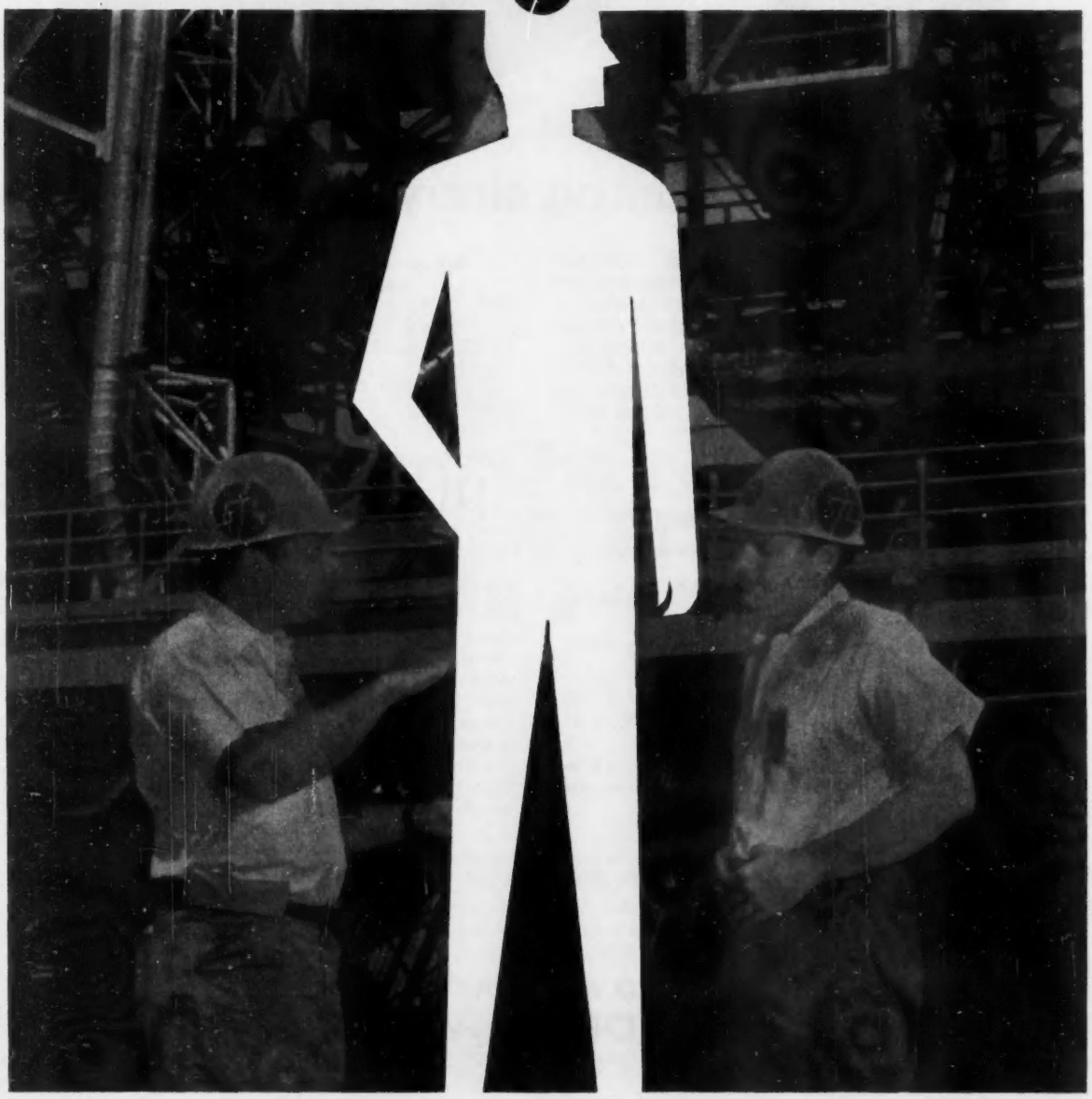
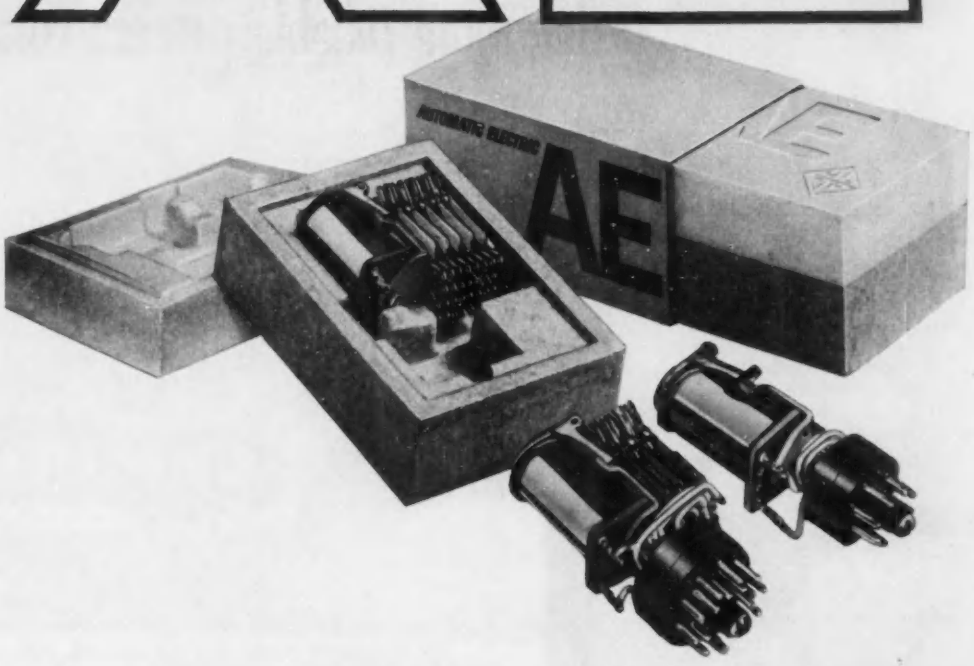


AE



TO THE ENGINEER

who wants his "circuit jewelry" intact

AE takes great pains in preparing its Class E relays for a well-adjusted life in the world of automatic control. To make sure that they reach you in the same happy state, we're now shipping them in a special protective package molded to shape from featherweight polystyrene foam.

The two sections of the case have identical multiform cavities. When put together, they form a snug fit for any Class E relay assembly. The possibility of relay damage in packing, in transit or in removal is virtually eliminated. To facilitate production, the containers can be fed directly to your assembly line; relays remain protected and accessible.

As for Class E relays, you can have them with the usual solder terminals, "Taper-Tabs," end-mounted printed circuit terminals, wire-wrap, prewired octal plugs, screw terminals or other special forms to fit your needs.

Our circuit engineers will be happy to work with you in applying Class E relays to your designs. They'll also be glad to tackle any control problems you may have.

Want details? Just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. And be sure to ask for Circular 1702-E, "Relays for Industry."

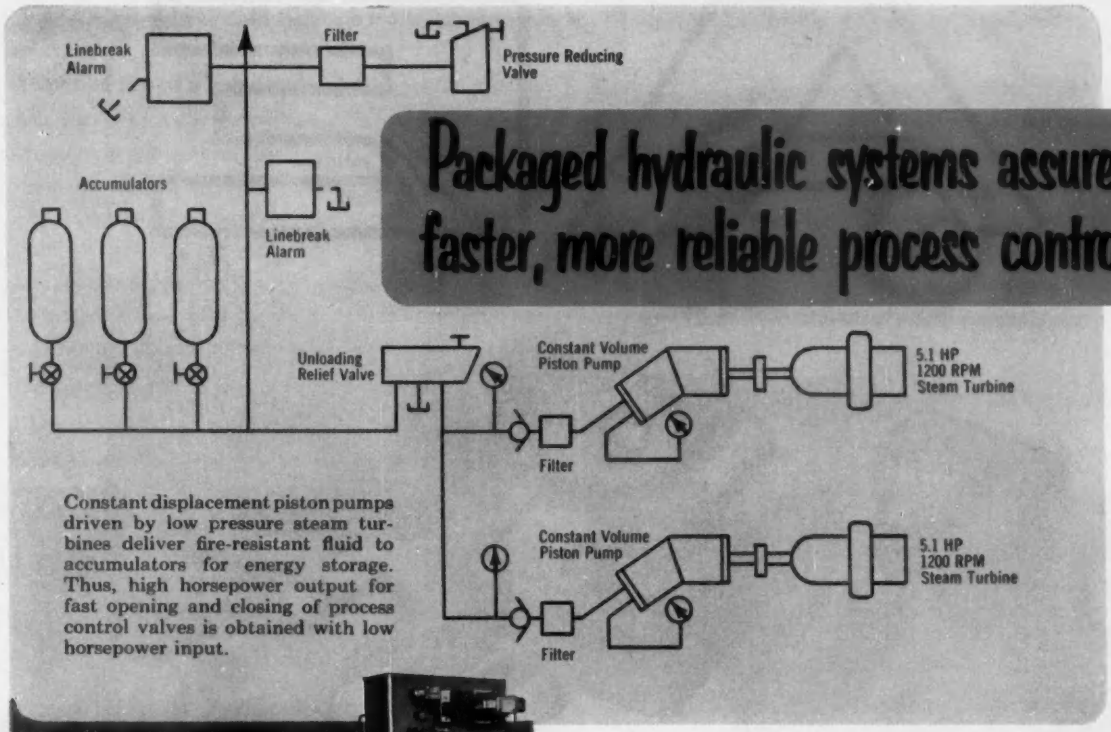
AUTOMATIC ELECTRIC

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

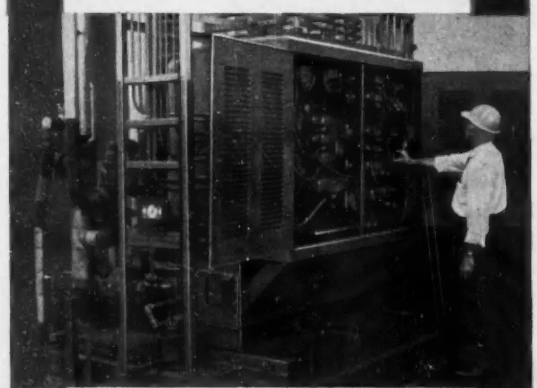
GENERAL SYSTEM

Packaged hydraulic systems assure faster, more reliable process control



Constant displacement piston pumps driven by low pressure steam turbines deliver fire-resistant fluid to accumulators for energy storage. Thus, high horsepower output for fast opening and closing of process control valves is obtained with low horsepower input.

Control console and power unit form electro-hydraulic system for controlling automatic heat treatment cycle. Physical layout provides optimum circuit efficiency, ease of servicing, and good appearance.



This power package includes all hydraulic pumps and valves for complete control of automatic cyclic operation of process in a butadiene plant.

Fast and precisely controlled motions, having the high reliability demanded by modern processing, are inherent characteristics of hydraulics. In addition, these advantages are obtained at low cost, for you can cover your full range of operations—from valve control to power transmission—with standard Vickers components. Your engineers enjoy unlimited design flexibility through a choice of electric, electronic, pneumatic and manual signals to control the hydraulic pumps, motors, cylinders, and variable speed drives.

Vickers complete packaged systems are ready to go into service upon arrival in your plant, since they are thoroughly pretested before shipment. They are properly designed and built to give maximum service life with little downtime, thus helping to keep your plant on stream.

Get more information on the job being done by Vickers packaged hydraulic systems in chemical, petrochemical, petroleum refining, and other processing industries by writing today for Bulletin I5802, "Packaged Hydraulic Systems for Process Control."

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New LFE Bernoulli Disk Data Storage Device weighs 6 pounds* . . . operates on 12 watts . . . resists 30g shock!

Originally developed for reliable storage and retrieval of data in outer space, this miniaturized unit introduces the BD-40 Series of customized LFE Bernoulli Magnetic Disk Memories . . . the simplest rotating storage devices ever developed.

These space-and-weight-saving units store data on a flexible magnetic disk. Their read/write accuracy under extreme shock and vibration conditions is maintained by a balance of forces generated by fluid flow together with centrifugal and curvature forces in the disk.

Compatible with all EDP systems requiring storage of information on a magnetic surface, the BD-40 Series combines the advantages of minimum size, weight, and power with ultimate reliability and immunity to adverse operating environments. Available with or without electronic circuits. For complete information, write for Technical Data Brochure.

TYPICAL SPECIFICATIONS BD-40 SERIES	
Dimensions — Inches	
Height	4
With Electronics	7
Mounting Flange	7.25 x 7.25
Weight — Pounds	
*Without Electronic Package	6
With Electronic Package	10
Power Requirements — Watts (approx.)	
Motor Drive (115v, 400 cps, 3 phase)	12
Electronics (+5, −5, +10, +15v D.C.)	3 non-recording
Environmental	
Temperature-operating	0° to 85°C
non operating	−60° to 125°C
Shock	30g pulse
Vibration 5 to 27.5 cps	±1.3g
27.5 to 52 cps	0.036 in.
52 to 500 cps	±5g
Capacity — (Nominal) — bits	40,000
Data Storage Tracks	32
Adjustable Registers	4
Clock and Timing Tracks	4

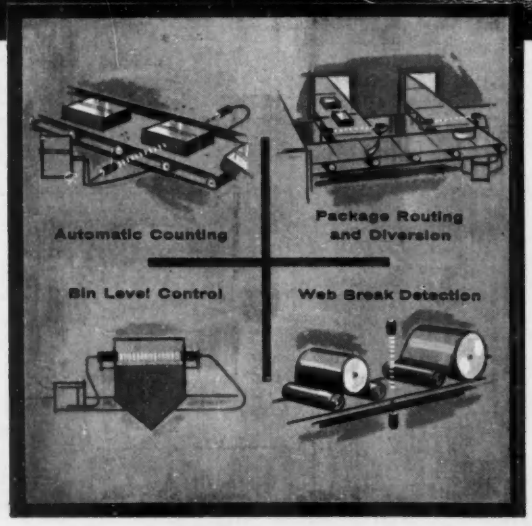
LFE
COMPUTER PRODUCTS DIVISION

LABORATORY FOR ELECTRONICS, INC.

1079 COMMONWEALTH AVE. • BOSTON 15, MASSACHUSETTS

"See a demonstration. 1961 IRE Show Booths 3819-3821."

a new dimension in automated controls

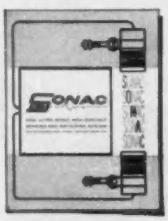


SONAC ULTRASONIC,

NON-CONTACT SENSING AND SWITCHING SYSTEM

Before Sonac, sensing and switching control systems which involved breaking a beam of energy were limited by vibration, dust, smoke, steam, air contamination and too much or too little light. Sonac's ultrasonic energy "beam" is completely free of these limitations. The acoustic lens on Sonac sensors can actually be painted without affecting performance. Utilizing high frequency sound also means there are no lamps to burn out. Savings in replacement parts and maintenance time often means Sonac pays for itself. Sonac is completely transistorized, providing you with a rugged, dependable electronic circuit.

These are just a few of Sonac's many uses. Optional equipment includes reflectors for precision beam and positioning control, and coupler assemblies for use with flexible tubing for remote sensor locations. This descriptive booklet will be sent to you on request.



DELAVAN
Manufacturing Company
WEST DES MOINES • IOWA

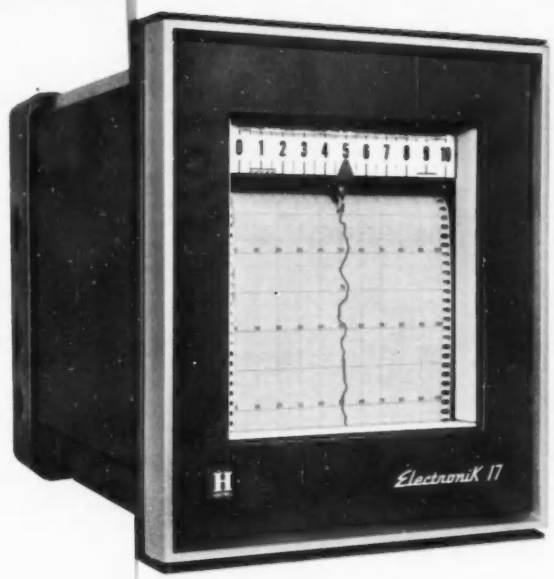
Now you can get . . . revolutionary rebalancing unit

. . . modular construction . . . ±0.25% accuracy . . .

in a small-case potentiometer . . . the advanced all-new

ElectroniK 17*

HONEYWELL



Now you can get . . . revolutionary rebalancing unit

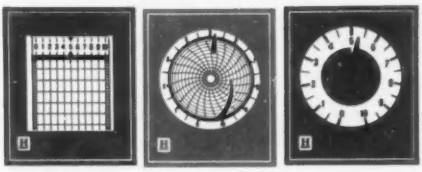
. . . modular construction . . . ±0.25% accuracy . . .

in a small-case potentiometer . . . the advanced all-new

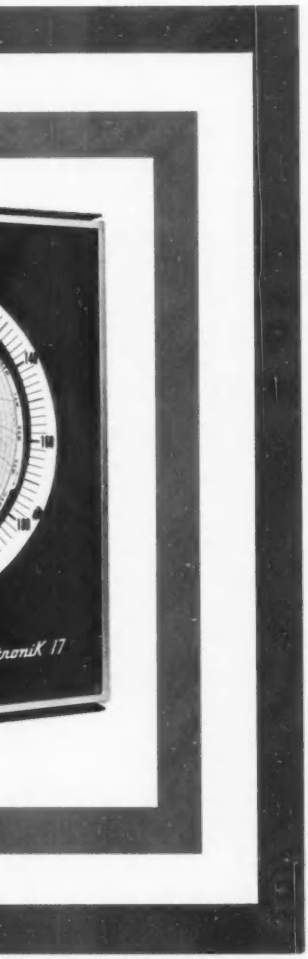
The *ElectroniK 17*

HONEYWELL

NO SLIDEWIRE
element, an in
works on the s
the resistance
linked to the
balancing moto
This in turn ca
sitioning the in
atmospheres a
and is unaffecte



17* will save you more time, trouble, dollars and maintenance than any other potentiometer on the market today.



- New STRANDUCER* replaces slidewire
- New control system with plug-in units
- New modular construction
- New economy

. . . and other pace-setting features.

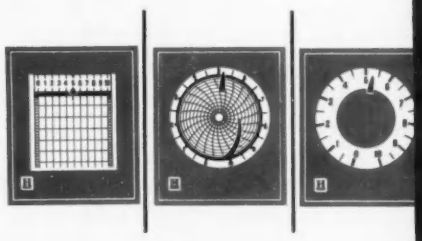
ElectroniK 17 potentiometers are completely new Honeywell recording and control instruments, compact enough to fit standard 19-inch relay racks. They perform reliably, have ±0.25% calibrated accuracy, and incorporate new design advances which make them the easiest of all potentiometers to operate, convert, and maintain.

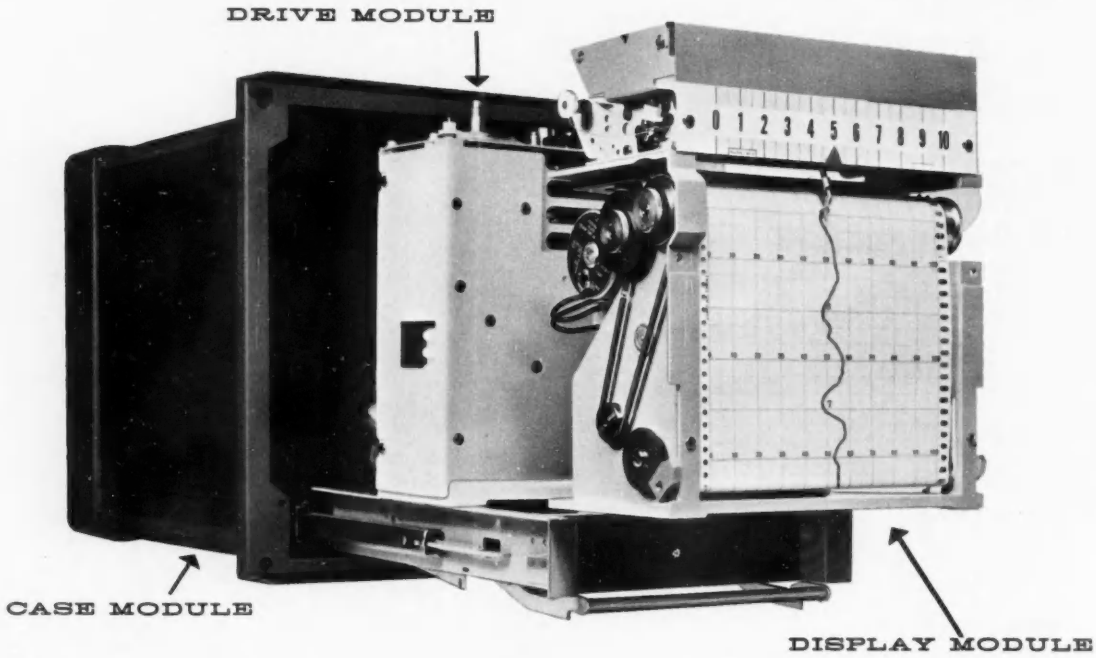
You can get *ElectroniK 17* instruments as strip or circular chart recorders or circular scale indicators. You can get electric contact control with up to 8 contacts. Control units are of plug-in type.

With *ElectroniK 17* potentiometers, you not only get uninterrupted performance, but also save money in initial cost, operating expense, and maintenance. You will find this new potentiometer far more economical to operate than any other available today. The following page will tell you why.

*Trademark

WIRE, NO SLIDEWIRE PROBLEMS. The unique STRANDUCER rebalancing
n innovation in potentiometer design, replaces the conventional slidewire. It
the strain gage principle and consists of four looped wire strands which form
nce legs of a Wheatstone bridge. Both STRANDUCER and pen carriage are
the potentiometer balancing motor. A change in electrical input causes the
motor to change the tension—and electrical resistance—of the STRANDUCER.
rn causes the balancing motor to rebalance the bridge, at the same time repo-
he instrument pen or pointer. The STRANDUCER is unaffected by corrosive
es and has no contactors. It has unusually long life and infinite resolution,
ffected when the instrument is subjected to ambient temperatures up to 130°F.





MODULAR CONSTRUCTION. *Modular construction and plug-in components make the ElectroniK 17 the easiest of all potentiometers to operate, convert, and maintain. Component interchangeability cuts service downtime, minimizes spare parts inventory.*

WIDE CONTROL POSSIBILITIES. You can have up to 8 control relays. Up to 8 plug-in contact control units fit into inside back of case.

INTERCHANGEABLE DISPLAY MODULE. You can switch easily from strip to circular chart, to circular scale operation . . . reduce your spare parts inventory because you can stock a single spare module for several instruments.

FRONT ADJUSTMENTS. You adjust damping and gain from the front of the instrument, using only a screwdriver.

QUICK-CHANGE DRIVE GEARS. You can change chart speed to ½ or 2 times basic speed in a matter of seconds by replacing quick-change drive gears. Standard basic chart speeds: 1, 2, 6, 10, or 60 inches per hour.

EASY RANGE AND ACTUATION CHANGE. Simply change range card attached to actuation board. A screwdriver is all you need. Universal reference junction compensator serves *all* types of thermocouples; you can quickly remove it to convert to some actuation other than thermocouple. Filter network rejects loop stray signals.

COMPACT EASILY-REMOVED TRANSISTOR AMPLIFIER. With only a screwdriver you can remove the amplifier for servicing.

NO STANDARDIZATION. Zener diode constant current unit does away with need for battery and standardizing mechanisms.

COMPACT CASE SAVES SPACE. With a height of 13¼ in., a width of 11 in. and a depth of 16⅝ in., the *ElectroniK 17* fits a standard 19-inch relay rack. Attach carrying handle to case, and you have a portable instrument. You need no tools to quickly remove door for easy access or conversion from one type of display module to another.

TERMINAL BOARD AND PULL-OUT CHASSIS You can pull out the chassis to the service position without tools and without interrupting the operation of the instrument, or completely remove it. Flexible wiring drawbridge keeps instrument operating when chassis is pulled out to service position, unplugs for removal of components. All external wiring connections go to terminal board at back of instrument case.

For complete information on the *ElectroniK 17*, call your nearby Honeywell field engineer or write to MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.—In Canada, Honeywell Controls Ltd., Toronto 17, Ontario.

Honeywell

First in Control

SINCE 1885

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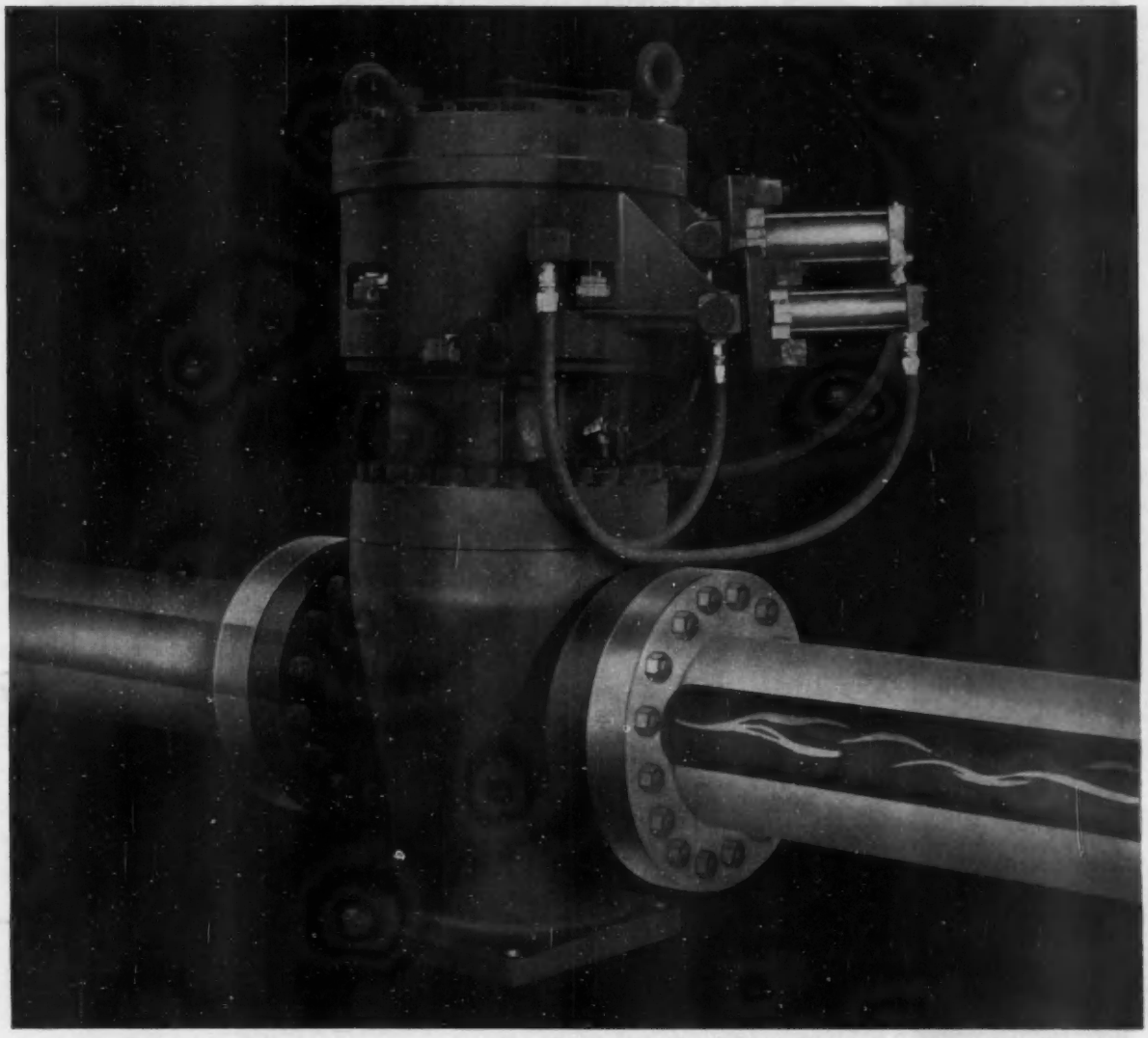
ALLIS-CHALMERS



Rotovalve is an Allis-Chalmers trademark.

Featured 8-in. Rotovalve stands 7 ft high and weighs 50,000 lb. Hydraulic operator works at a pressure of 3000 psi . . . a speed of 1/10th second!

"Putting a stop" to 2500 psi at 2500 F

...here's the valve that does it with ease!

This 8-in. *Rotovalve* takes extreme conditions in stride . . . handles 2500 psi at 2500 F. Constructed of chrome-moly steel, it employs internal air cooling to maintain valve temperature at 1000 F despite the *far higher* heat of the liquid or gas being handled.

Allis-Chalmers cone valves *seat even tighter with use* . . . feature lantern ring with double packing, pressurized with the line fluid or purged to a bleed tank at lantern ring. Both standard and special *Rotovalve* units have proved their reliability in thousands of applications, under widely varying conditions.

Any time you face a valving problem, call on your Allis-Chalmers representative. He's equipped to supply "specials" engineered exactly to your application. And he also offers you a complete line of Rotovalve *units and butterfly valves for conventional uses. Contact him for information, or write* **Allis-Chalmers,** *Hydraulic Division, York, Pa.* A-1394

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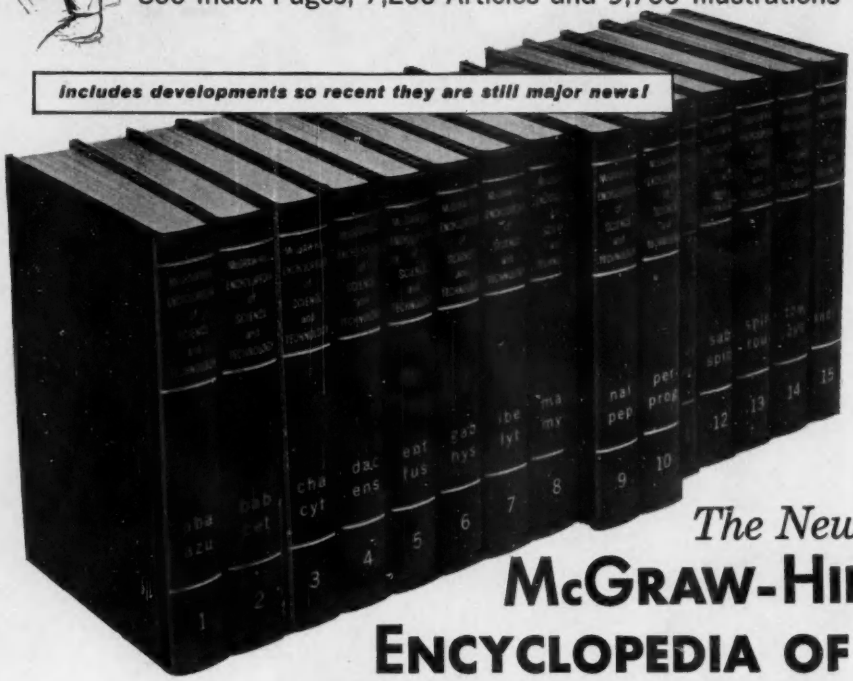

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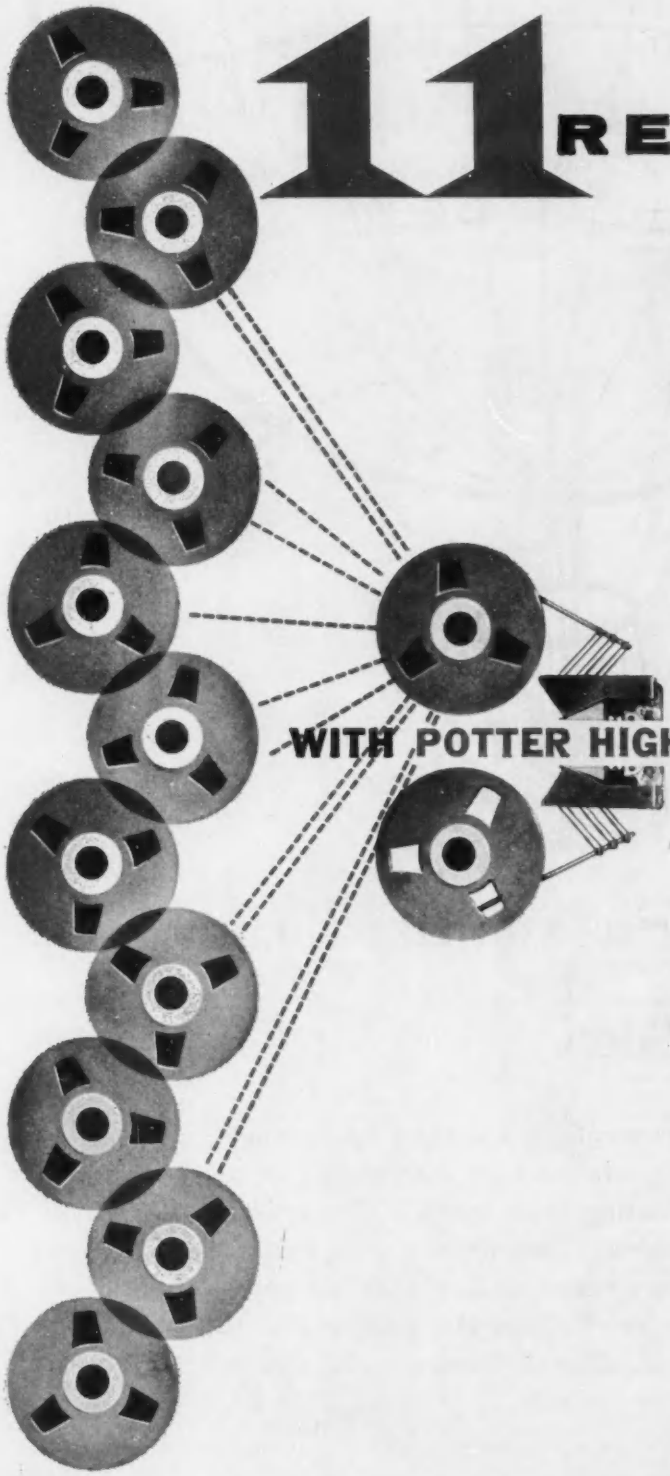


11 REELS IN 1

With the revolutionary new Potter High Density Recording System, each reel of 1-inch tape holds as much data as 11 reels recorded by the most widely used computer tape system.

For highly reliable computer applications, Potter High Density recording can give you data transfer rates of 360,000 alphanumeric characters per second or more, at densities to 1500 bits per inch on 1-inch tape. Sixteen parallel channels can be accommodated on one-inch tape. Because Potter has made the information channels self-clocking, no separate clock channel is needed, and multichannel data can be read out in true parallel form, despite interchannel time displacement.

WITH POTTER HIGH DENSITY RECORDING

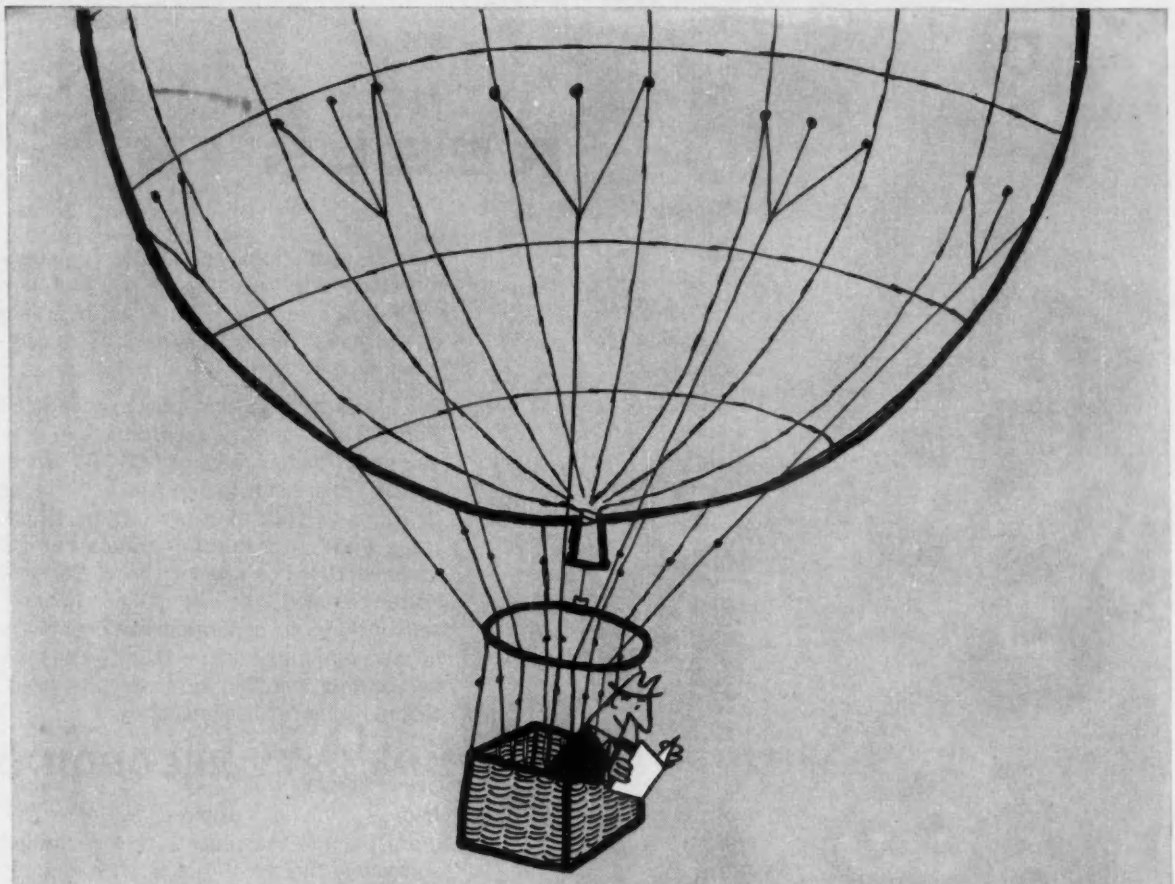
In production units delivered by Potter, this dramatic new technique makes recording so reliable that in 40 hours of continuous operation, less than 2 seconds re-read time are required to recover information lost through transient error. Dropouts are fewer than 1 in 10^7 at densities up to 1500 bits per inch. More than 20,000 passes of the tape can be made without losing information or significantly increasing the dropout rate.

Tested and proven in computer systems, Potter High Density Recording is presently available in the Potter 906II High Speed Digital Magnetic Tape Handler, and will be available in other Potter Tape Systems.

Write today for details on how High Density Recording can be applied to your data handling problem.

See us at the IRE—Booths 3405-3407

POTTER INSTRUMENT COMPANY, INC. • SUNNYSIDE BOULEVARD, PLAINVIEW, NEW YORK



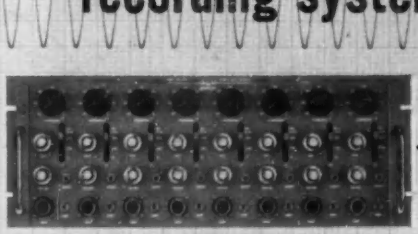
Professor Lucius von Hausen, of aeronautics fame, reads in a balloon.

"Sort of keeps me on top of things," he says. Fair enough . . . but other engineers and executives prefer to read with their feet on the ground, especially when they're reading about business. Remember, a good place to read is a good place to think . . . and if you pay engineers and managers to think, encourage them to do more reading. Like so many successful men who read their "most useful" McGraw-Hill publications, they'll find the best place . . . home or plant, office or hammock. But wherever they read, remember, you share in the rewards.*

**Yes, when they read, you profit, too. Write on your business letterhead for a personal copy of booklet, "The McGraw-Hill Engineered Reading Program."*

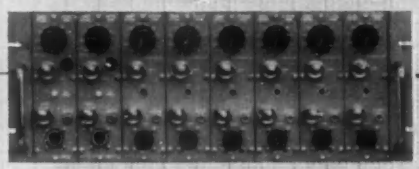
Sanborn
has probably already designed your "custom" oscillographic recording system

"Building block" recorder and amplifier design permits maximum flexibility to meet specific application needs



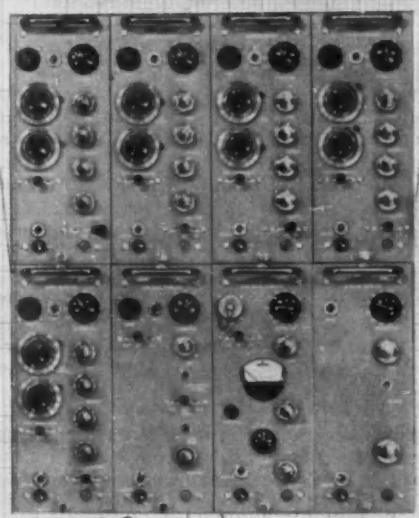
950 Series — truly low cost — identical channels

6 or 8 identical DC recording channels — either high gain, 10 uv/div; medium gain, 0.5 mv/div; or low gain, 10 mv/div. Medium and high gain types are completely transistorized, have floating and guarded input circuits. Frequency response DC to 150 cps within 3 db, 10 div peak-to-peak with low and medium gain systems, to 100 cps with high gain system. Amplifier panel space only 7" x 19", recorder 17½" x 19".



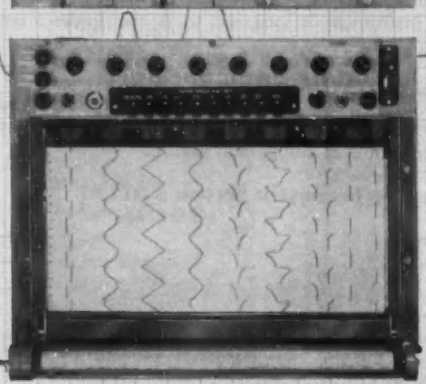
850 Series — economical, flexible — miniature plug-in preamps

Interchangeable plug-in preamps, eight to a 7" high module, available in Phase Sensitive Demodulator, DC Coupling, Carrier and Low Level types. System response to 150 cps within 3 db, 10 div peak-to-peak, depending on preamps used. Input circuits single-ended, push-pull, or floating and guarded, depending on choice of preamp.



350 Series — versatile, high performance — interchangeable preamps

Provides greatest possible application flexibility, with interchangeable preamps in Carrier, DC Coupling, Phase Sensitive Demodulator, Differential DC, Low Level, Logarithmic and Frequency Deviation types. System response DC to 150 cps within 3 db at 10 div peak-to-peak — input single-ended, floating and guarded, or push-pull — depending on preamplifier used. Eight preamps in two 4-unit modules occupy 21" x 19" of panel space; usable separately with individual power supplies to drive meters, 'scopes, etc.



"350" style Recorder Assembly — used in all the above systems. Provides transistorized, plug-in, current-feedback power amplifiers . . . low impedance, velocity feedback damped galvanometers . . . 8" of visible record . . . 9 electrically controlled chart speeds . . . inkless traces on rectangular coordinate charts . . . flush front recorder, vertical chart plane. Recorders with horizontal chart plane also available for 350, 850 and 950 systems.

Sanborn oscillographic recording systems also include the tube-type 1- to 8-channel "150" Series with 12 plug-in preamplifiers; and the "650" 1- to 24-channel optical oscillograph with response to 5 KC and 8-channel amplifier available separately for driving any galvanometer. For complete data contact one of the Sanborn Sales-Engineering representatives located in principal cities throughout the United States, Canada and foreign countries.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Massachusetts

SEE THIS EQUIPMENT AND OTHER SANBORN OSCILLOGRAPHIC RECORDING SYSTEMS, AMPLIFIERS AND TRANSDUCERS ON DISPLAY AT BOOTHS 3701-03-05, I.R.E. SHOW, NEW YORK COLISEUM, MARCH 20-23.

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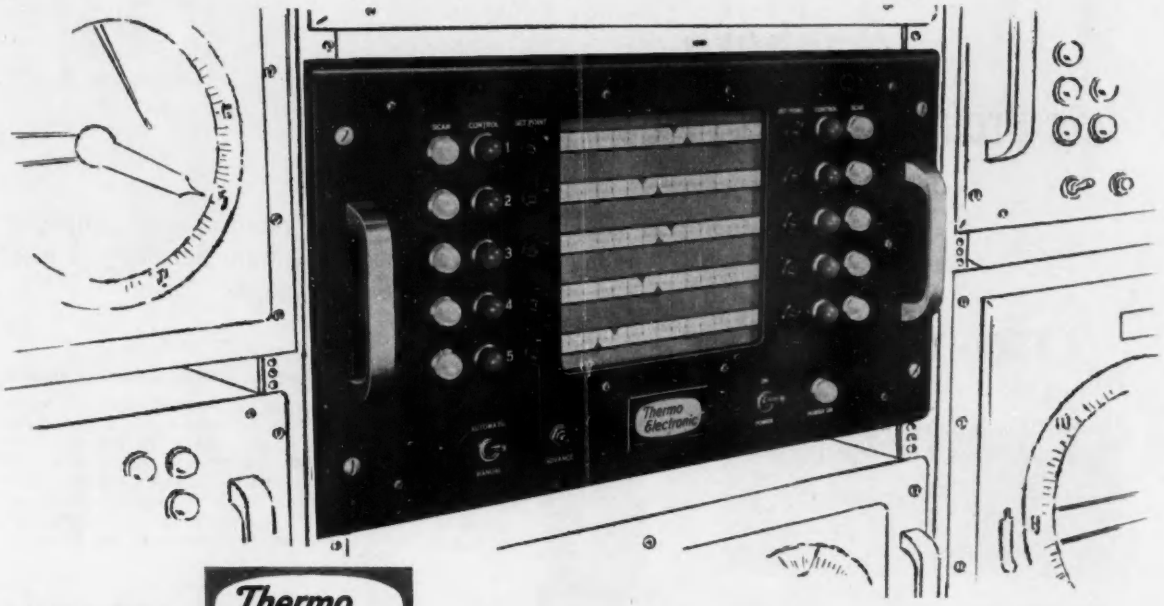


ONE Thermo Electronic Multi-Point Controller

Controls TEN Process Temperatures

One, compact "Thermo Electronic" Multi-Point Controller gives you, sensitive, accurate, automatic . . .

- Two position (off-on) control of up to ten separate process temperatures; also controls flow, pressure, pH, Strain gages, and other operations.
- Three position control of five separate processes!
- Single point constant control of any critical process!
- Manual-Balance Indication of exact process conditions!
- Monitoring of extra points or those already under control!

Ten in One

One instrument does the job of ten individual controllers. You save—40 to 60% of initial cost—up to 75% of panel space —cut installation time and cost—minimize maintenance!

Clean, Simple, Functional Design

The "Thermo Electronic" Multi-Point Controller has front-set controls for easy operation. Routine maintenance is also done from the front, without removing unit from panel or relay rack. Available in either potentiometer or bridge measuring circuits, with an extremely stable constant voltage supply, the instrument provides long-lived, trouble-free control of practically every process suitable to off-on control action. Sensitivity is 15 microvolts independent of scale span—Accuracy is ±0.5% of scale span.

Operation

Sensing element input signals are compared, in sequence, to individually adjustable slide-wire set-points. Signal deviations are amplified by the "Thermo Electronic" high-gain relay control amplifier, and used to actuate load relays connected to the points being controlled.

Scanning sequence is governed by a stepping switch and electronic timer. Scanning rate—3 seconds per point. Other scanning speeds are available by simply changing one carbon resistor.

Ten white lights on the instrument panel show scanning position—ten red lights show process condition. Ten knobs permit adjustment of individual set-points on the range scales. Ranges are available for thermocouples, resistance temperature detectors and other types of suitable transducers.

Maintenance is Easy

The instrument slides forward on built-in tracks. Simple adjustment and inspection is easily accomplished from the front. The plug-in or screw-terminal components are easily replaced—fully protected from dirt and corrosive atmosphere. The whole instrument is gasketed to further protect components.

Safety Engineering

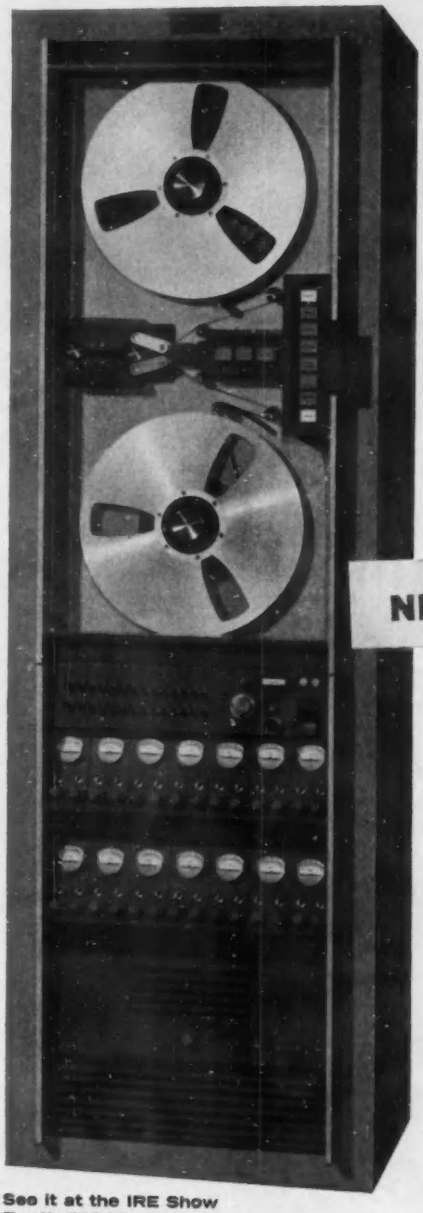
Critical circuitry is fused against overloading. A failsafe circuit is provided to protect processes against thermocouple burn-out and amplifier component failure.

Write today for Instrument Section 52-11

Thermo Electric

Temperature Measuring Systems and Components

THERMO ELECTRIC Co., Inc., Saddle Brook, New Jersey
In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ont.



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NEW THIS MONTH – 300 kc/60 ips

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Booth #3243

NEW MINCOM Model G-100 Recorder-Reproducer

Write for brochure

1. Greater dynamic range
2. 200 cps to 300 kc at 60 ips
3. All-transistorized "card system" modules
4. FM and Direct recording/reproducing
5. 14 tracks–one rack
6. Lower power requirements

3M COMPANY ... WHERE RESEARCH IS THE KEY TO TOMORROW

MINCOM DIVISION **M**INNESOTA **M**INING AND **M**ANUFACTURING COMPANY

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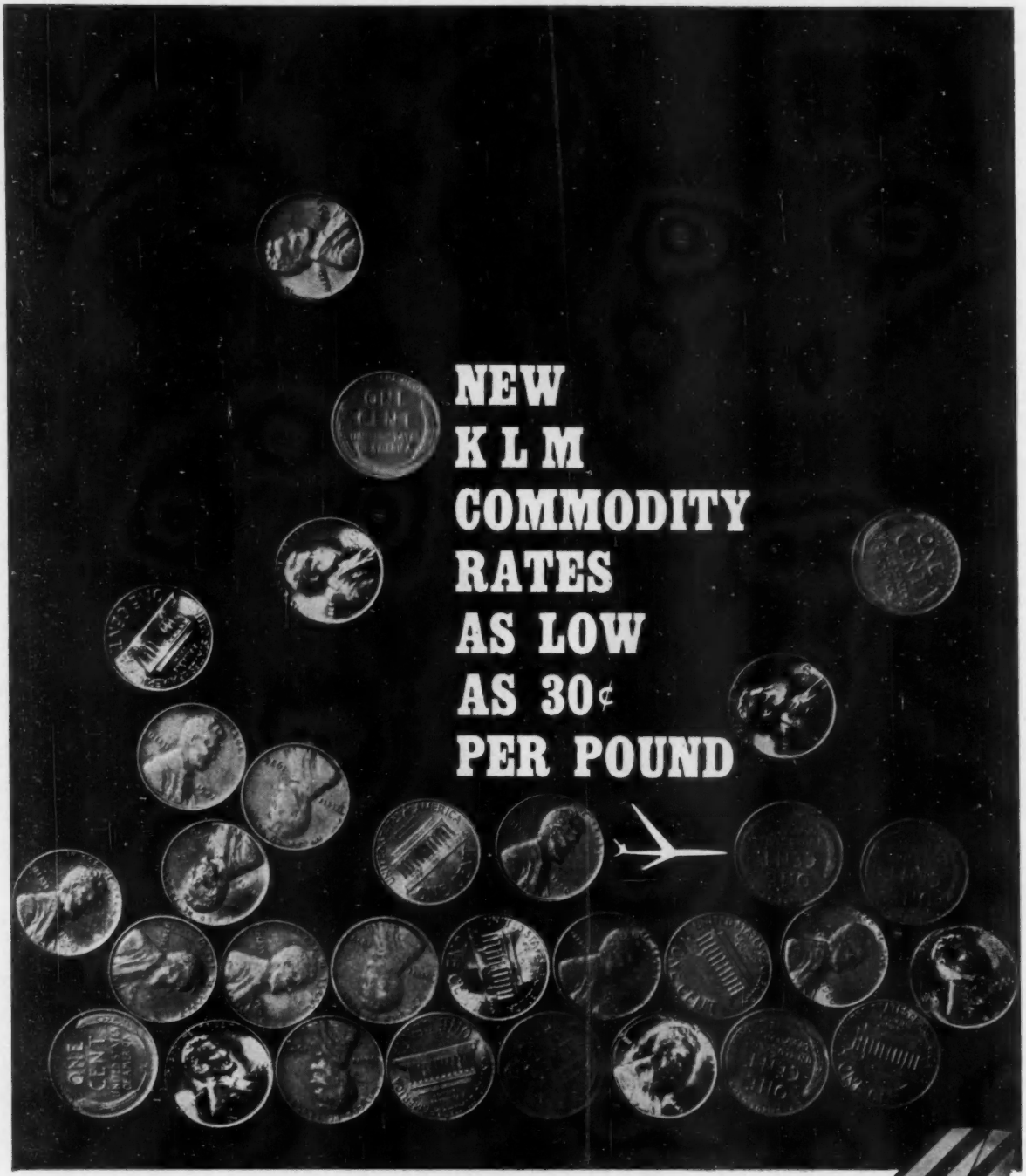

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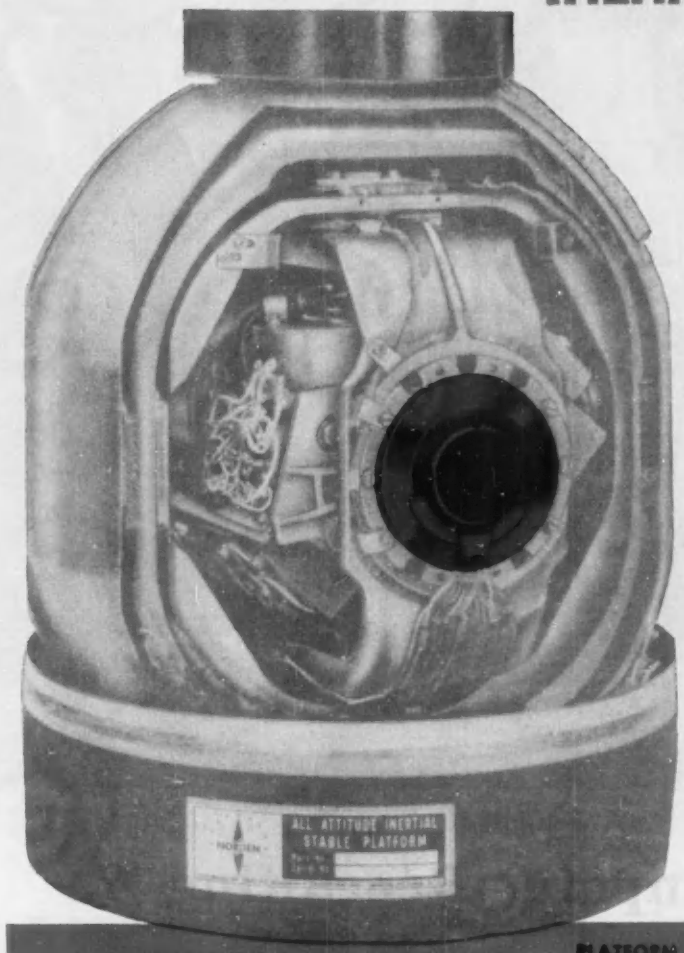
THE WORLD OVER
KLM
ROYAL DUTCH AIRLINES

INLAND d-c torque motors save critical weight in guidance systems



PLATFORM SHOWN ⅓ SIZE

Norden Miniature All-Attitude Inertial Platform uses four Inland torque motors, one for each gimbal axis.

Norden specifies these Inland d-c torque motors because of their compact pancake shape, low-power input and direct torquing. In addition to providing the obvious weight and space reduction, Inland's direct drive positioning eliminates gear train problems such as backlash.

Norden engineers say, "The linearity of the Inland torquers is excellent over a wide range so that precession rates may be accurately established. The torquer fixed field is carefully stabilized so that the torquer gradients will be constant over long periods of time."

Inland d-c pancake torque motors with high torque-to-inertia ratios and linearity of output provide all the advantages of direct gearless servo positioning in a complete line over the full range of 0.1 to 3,000 pound-feet.

COMPARE THESE TYPICAL INLAND TORQUER RATINGS

	T-1321-A	T-2136-A	T-2108-B
Peak torque, oz. in.	20.0	35.0	60.0
Volts at peak torque, stalled at 250°C	48.0	26.0	25.6
Amps at peak torque	1.21	1.6	1.24
Total friction, oz. in.	0.5	0.8	1.5
Rotor Inertia, oz. in sec²	.001	.007	.011
Weight, oz.	5.0	9.0	14.0
Dimensions (inches):—O.D.	1.937	2.81	2.81
I.D.	.625	1.00	1.00
Thickness	.50	.63	1.00

For complete catalog with engineering data, outline drawings and specifications on these and other Inland d-c pancake torquers, write Inland Motor Corporation of Virginia, Northampton, Massachusetts. Dept. 5-3.

INLAND MOTOR CORPORATION OF VIRGINIA

A SUBSIDIARY OF KOLLMORGEN CORPORATION

NORTHAMPTON, MASS.

CIRCLE 79 ON READER SERVICE CARD

What is "Pinpoint Recruiting"?

It is the act of going directly to the most concentrated source of supply to find 'the right man' for the job.

Control Engineering is his professional literature. Through its consistently high calibre editorial content, he keeps pace with developments in measurement and control and information systems. The design and application of these are his broadgauge field. His forte is computer engineering and programming, systems analysis, equipment design... the whole range of disciplines contributing to today's most dynamic technology.

Your most direct link to 'the right man' is in the pages of the publication he makes it his business to read.

Write for the 20-page file-size booklet "How to Attract Engineers"
Address: David Hawksby, Classified Advertising Division,
Control Engineering, Post Office Box 12, New York 36, N. Y.

The man you need is the man who reads

Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

Ask Your *FISHER/MAN* How To

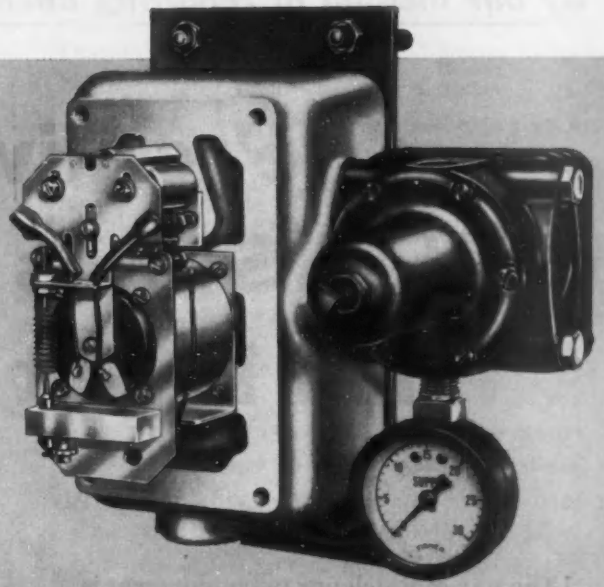
SPEED THE INPUT SIGNAL to the CONTROL VALVE

FISHER

TYPE

543

ELECTRO PNEUMATIC TRANSDUCER



Available with or without a pneumatic valve positioner

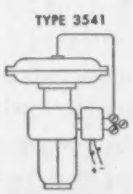
Here's an electro-pneumatic transducer developed for use in electrical control loops where the final control element is pneumatically operated. Explosion proof design makes it ideal for use under hazardous conditions. Input signals may range from 1 to 5 ma. through 10 to 50 ma.... output from 3 to 15 psi through 6 to 30 psi. Built-in volume relay permits direct operation of the pneumatic actuator from the Transducer. No extra relays or boosters needed. Relay can be serviced independent of electrical assembly. Unit is completely reversible by reversing input leads and rezeroing.

If you want additional information on the Type 543 Electro-Pneumatic Transducer write Fisher Governor Company.

TYPICAL CIRCUITS		
Input Current	Load Requirements of Controller	Actual Internal Resistance of Transducer
1 to 5 ma dc	3,000 ohms maximum	2,500 ohms ±125 ohms
1 to 5 ma dc	12,000 ohms ± .5%	12,000 ohms ± 50 ohms
10 to 50 ma dc	500 ohms maximum	57 ohms ± 4 ohms

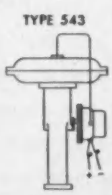
PERFORMANCE DATA	
Linearity	1% of full range
Air Consumption Rate	2 SCFH with 15 psi output pressure
Resolution Sensitivity	.05% of input range
Frequency Response	Complete frequency response data with Fisher topworks available

TYPE 3541



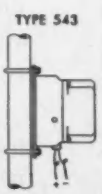
Electro Pneumatic Controller Mounted on Control Valve

TYPE 543



Transducer Mounted on Control Valve

TYPE 543



Transducer Mounted on Stand Pipe

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD... CHANCES ARE IT'S CONTROLLED BY...

FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / London, England

CONTINENTAL EQUIPMENT CO. DIVISION, Coraopolis, Pennsylvania

FISHER® Controls

SINCE 1880

By our method of reporting unemployment...

We're Giving The United States A Black Eye That Is Not Deserved

The way in which our unemployment is reported is giving the United States an undeserved black eye around the world. The broad concept of unemployment we use exaggerates the amount of unemployment in the United States as compared to most other countries. Our reporting system also falls short of presenting a balanced picture by concentrating on people who are idle, while neglecting jobs that are idle because people cannot be found to fill them. This editorial explains these defects and suggests improvements.

The *Monthly Bulletin of Statistics*, issued by the Statistical Office of the United Nations, has become a standard reference for international comparisons of economic performance, including employment and unemployment. Here, from the November, 1960 issue, is part of a table giving comparative figures on the rate of unemployment for the United States and a group of European countries:

	UNEMPLOYMENT RATE	
	Annual Average 1959	Jan.-June Average 1960
West Germany	2.4%	1.0%
Netherlands	1.8	1.4
Sweden	2.0	1.8
United Kingdom	2.3	1.9
United States	5.5	6.1

A Distorted Picture

If taken at face value the table clearly says that the United States is doing far worse in providing jobs for its citizens than the other countries whose unemployment records are listed.

But the figures are deceptive. They are made so, in part, by our government's use of a much broader concept of what constitutes unemployment than is used by most other countries.

Sweden provides a clear case in point. The table indicates that during 1959 Sweden had an unemployment rate of 2.0%, while the rate in the

United States was 5.5%. But a report from Sweden, published in the U.S. Department of Labor's *Labor Developments Abroad*, indicates that if they had used the same methods of calculating unemployment as we, the reported jobless rate in Sweden would have almost doubled. Thus a large portion of the gap between the unemployment rate in the United States and the unemployment rate in Sweden would have been eliminated.

Graduation To Unemployment

In general, countries listed in the table use registrations at public employment agencies as the basis for calculating their unemployment. Our Department of Labor, in making its sampling of unemployment, includes unregistered young people who are waiting for jobs or training opportunities as well as housewives who are looking for jobs in a general sort of way but who have not registered anywhere in search of them.

It used to be that graduation from college was regarded as a day for great celebration and rejoicing. But, because of the way the Labor Department does its counting of unemployment, it is now a day of sorrow. For unless our young people immediately rush off to jobs, they graduate into unemployment and swell our jobless figures.

While our government very expansively counts all the unemployed, there is no offsetting report on the number of jobs that are unfilled because no one qualified can be found to fill them. Currently there are many jobs in this category, and it is to be expected that there will be more as the technological revolution picks up momentum.

A properly balanced report on unemployment would include a record both of people who are idle, as conceived on some standard international basis, and jobs that are idle. A combination of the two sets of data would provide a much better indication of the economic health of a nation than unemployment alone.

The United Kingdom regularly collects figures on unfilled jobs as well as the number of unemployed. Thus it is not an impossible task to collect information on idle jobs. **For a fast moving economy, such as ours, the collection of statistics on unfilled jobs presents special difficulties. But this information is so important that Congress should see that it is added to our employment and unemployment records.**

A National Disservice

There is not the slightest inclination here to minimize the amount of unemployment in the United States at any time, or the crucial importance of doing everything possible to keep it at rock bottom. If the reporting of unemployment were simply for domestic consumption, it would be possible to make an appealing case for using a very broad conception of it. This is one way of underlining the importance of the problem.

But when, as is the case, international comparisons of unemployment are treated as key gauges of the effectiveness of different economies, we do ourselves an important national disservice by using an exceptionally commodious concept of unemployment. American travelers abroad can testify that they are continuously being called upon to explain why the United States does such a relatively poor job in providing employment for its people. This is an unwise and unfair burden to impose upon the nation. **We make enough mistakes of economic commission and omission without issuing reports that distort our economic performance to our own discredit abroad.**

This message was prepared by my staff associates as part of our company-wide effort to report on major new developments in American business and industry. Permission is freely extended to newspapers, groups or individuals to quote or reprint all or part of the text.

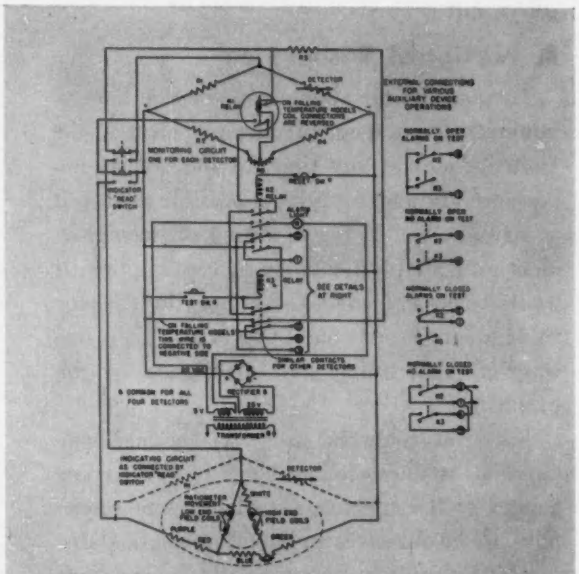
Donald C. McGraw

PRESIDENT

McGRAW-HILL PUBLISHING COMPANY

Questions and Answers on the EDISON OMNIGUARD SYSTEM

The Most Effective Means of Measuring and Safeguarding Temperatures and Pressures



Q. How does the Omniguard System work?

A. Edison's Omniguard is characteristically simple and unique in its operation. Each Omniguard channel is a conventional D-C Wheatstone bridge circuit in which an Edison temperature or pressure detector forms the variable leg of the bridge. As the temperature or pressure rises and falls, the detector resistance increases or decreases. An Edison relay (K1) across the bridge senses the current flowing through it. When conditions are normal the current flows in the direction to hold the relay contacts open. When a variation occurs, however, current flow reverses and the contacts of this alarm relay close. Relay K1 energizes the coil of auxiliary relay K2 which actuates an alarm light on the panel face to show which detector is "off-normal," actuates an external alarm or annunciator and maintains the alarm indefinitely — until conditions have returned to normal and the normally closed reset switch is opened.

Any temperature or pressure can be read at any time by pressing the indicator read switch for that point.

Q. Is Omniguard dependable?

A. Reliability is built in. Since each measuring channel is an independent, separate circuit, complete system failure is unlikely. Only the most reliable components are used. Edison resistance temperature detectors don't "drift" over years of service. There are *no* scanning mechanisms to wear out . . . *no* delicate components . . . *no* electronic circuits . . . *no* amplifiers . . . *no* periodic maintenance requirements.

Q. Is Omniguard flexible?

A. Completely. A system can monitor as few as 4 or as many as hundreds of variables. Buy only what you need. Since channels are independent of one another, each can be set to alarm at a different temperature or pressure. Alarm settings can be changed easily and quickly.

Omniguard can be used for alarm or shut down of equipment, alarm can be local and remote, is easy to telemeter to remote control station.

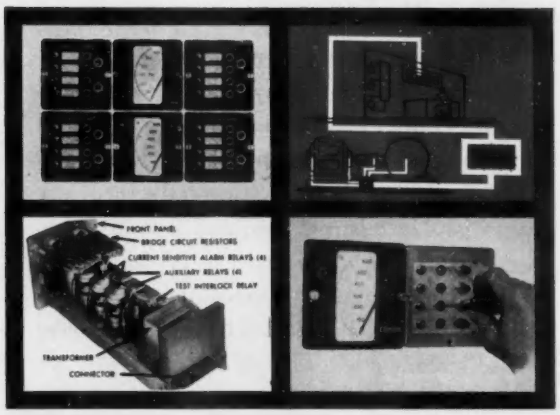
Q. Is installation economical?

A. Omniguard is the simplest system available. Fewer parts mean lower costs, less maintenance. Plug-in monitors are installed in minutes with no special tools or calibration. Ordinary copper wire connects remote detectors to monitors. Monitor units act as their own annunciators, identify each temperature and pressure, eliminating the need for extra equipment in most installations. Omniguard is a *complete* system with all parts including hardware supplied by Edison.

Q. How accurate are Edison's Resistance Temperature Detectors?

A. In the range from −200°F to +1350°F, no other type of detector is as stable, sensitive, and accurate over years of service. Response times of 0.8 seconds are common — detectors are repeatable to .05% over years of use, resistance being directly proportional to temperature.

Resistance Pressure Detectors are accurate to 1% or better depending on pressure range.

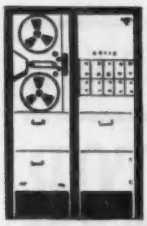


For complete information on the Edison Omniguard System, industry's simplest, most reliable means of continuously monitoring critical temperatures and pressures, write for Bulletin 3036C.

Thomas A. Edison Industries

INSTRUMENT DIVISION

38 LAKESIDE AVENUE, WEST ORANGE, N. J.



The lower end of the frequency spectrum has become a focal point for important motion studies involving submarines, ships, helicopters, trains, and automobiles. Honeywell's latest contribution in this area is the LAR 7500 Magnetic Tape System. By combining savings in manpower and tape with increased flexibility in playback speeds, the LAR 7500 brings new economy and convenience to long-term studies of low frequency phenomena.

This system is the ideal recording tool for motion studies extending down to zero frequency. Time base changes can be provided on playback within a range of *real time to 1000:1*. In addition, the LAR 7500 lets you playback over a large range of speeds *without changing heads, belts, or pulleys*. And with the use of thin base tape, this system gives you better than *two days of motion recording* with each 14″ reel.

Get all the facts on the new LAR 7500 Magnetic Tape System by calling your nearby Honeywell field engineer. He'll give you valuable assistance in matching a Honeywell data system to your exact requirements. Be sure to ask about the Honeywell Automatic Wave Analyzer Systems for accurate and high-speed analysis of recorded data.

MINNEAPOLIS-HONEYWELL, Industrial Systems Division, 10721 Hanna Street, Beltsville, Maryland.

Honeywell

First in Control

SINCE 1906

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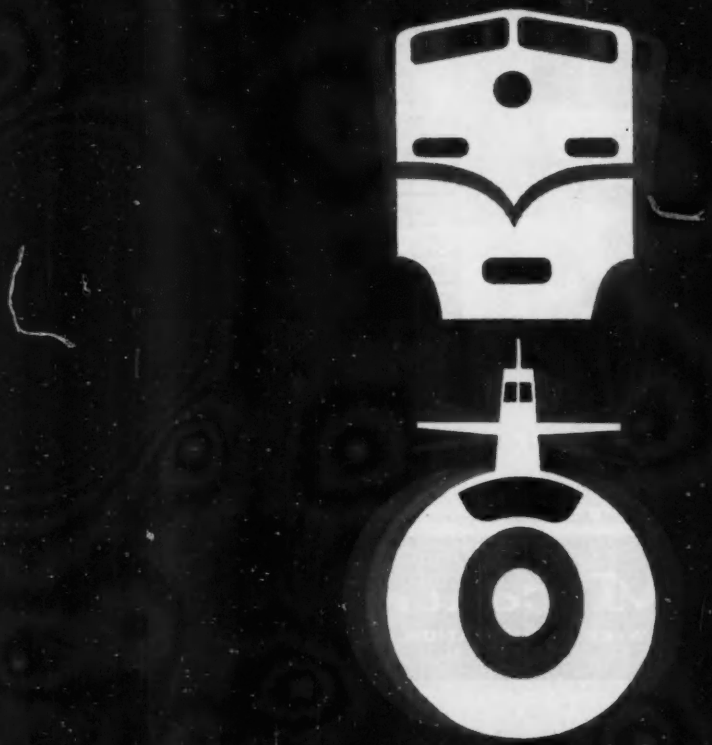
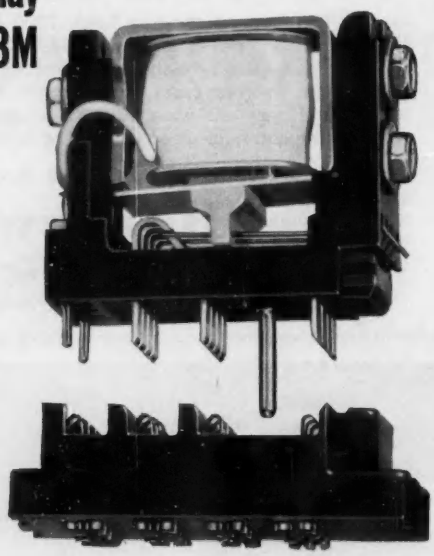
THE STRANGE LANGUAGE OF MOTION



New Relay from RBM



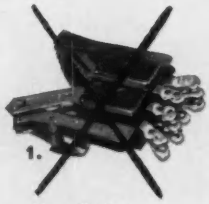
Compact, Rugged, Proven Reliable

THE DIRECTOR

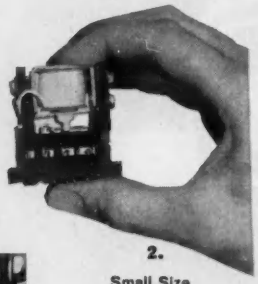
TYPE 81 WIRE CONTACT RELAY

Specifically designed to direct or set-up circuits in the logic or arithmetic section of computer and business machines. The RBM "Director" has also demonstrated itself ready to perform in similar applications where the basic function of the contacts of one or more relays sets up a circuit, but is not required to make or break that particular circuit. Typical uses would be controls for automation, railway signaling, traffic controls, chemical process controls, annunciators and many others.

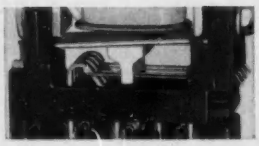
Designed for high speed and long life (200 million operations).



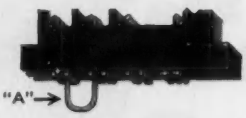
1. No soldering



2. Small Size

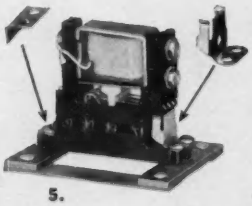


3. Wire contacts

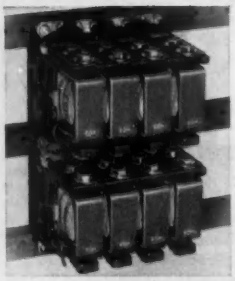


"A"→

4. Program connectors



5. Rugged snap-in plug assembly



6. Rack mounting

1. Plug-in terminal and mating terminal block eliminates messy soldering and maintenance problems of old fashioned telephone type relays.

2. Symetrical shape and rugged design provides for minimum mounting space and maximum protection to moving parts when handling.

3. Armature contacts consist of two silver alloy wires per pole providing highly reliable redundant contact surfaces.

4. With plug-in connectors "A", relay contacts can be "programmed" to suit specific circuit requirements.

5. Special hardware available allowing for mating terminal block assembly and easy mounting on chassis or rack.

6. The Type 81 relay can be easily assembled in groups, simplifying wiring and ease of programming. Requires minimum rack or chassis space.

TYPE 81 SPECIFICATIONS

Contact Form	4 PDT
Contact Rating	3 amp. (carry only)*
Contact Material (Std.)	Eutectic Alloy—Silver-Copper
Operating time (Nom.)	5.5 milliseconds max. inc. bounce
Life	200 million operations
Coil Form	Single or Double Winding (Pic & Hold)
Coil Voltage	20 volts D.C. thru 115 volts D.C.
Coil Power	4 watts max.
Breakdown Voltage	1250 volts RMS 60 cycle to frame
Ambient Temperature	50° C
Weight	Approximately 1¾ oz.
Overall dim. (Approx.)	Including plug—2⅛" x ⅝" x 2"

**Consult Factory for Ratings for Making and Breaking Loads.*

Consult Your Local RBM Product Application Engineer or Write for Bulletin 2000

CONTROLLING THE FUTURE

RBM Controls Division

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA

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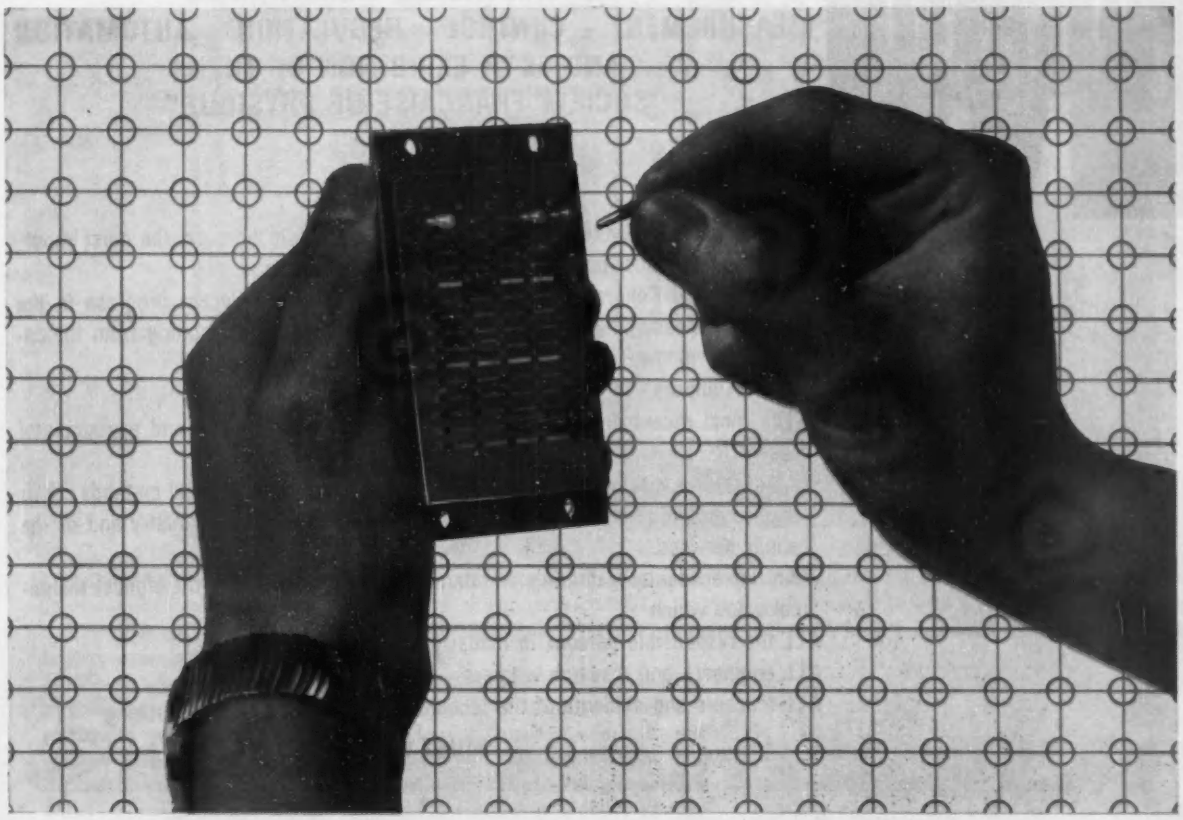
PIN POINT PROGRAMMING

AMP PINBOARDS can do a host of dry circuit switching or commoning functions . . . permit numerous matrixes in one assembly. Complicated switching functions can be accomplished by simply inserting or removing a pin.

You can use these **PINBOARDS** as modular building blocks for instrumentation applications, automated tooling, test equipment, data processing . . . any variety of size and grid arrangements in multiples of a basic 15 x 5 hole pattern. Contact springs can be bussed in any combination desired. And for safety, there are no exposed conducting surfaces on the rear side of the board. The conducting area of the pin is safely inside board before contact is made with mating springs.

AMP PINBOARDS are factory pre-wired to your specifications . . . with standard or special silk screen legends. Designed for simplicity . . . flexibility . . . reliability . . . with three amperes continuous current rating.

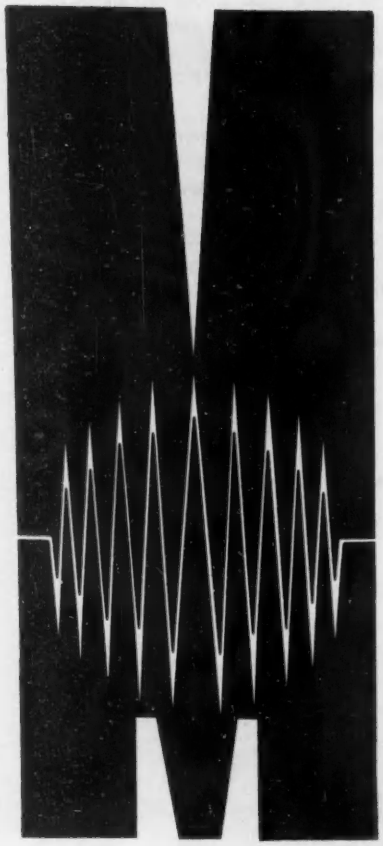
Write for complete specifications.



AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

AMP products and engineering assistance are available through subsidiary companies in: Australia • Canada • England • France • Holland • Italy • Japan • West Germany



PARIS FROM MAY 9TH TO MAY 17TH 1961

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"SOCIÉTÉ FRANÇAISE DE PHYSIQUE"

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- The most recent discoveries and appliances of the theoretic and experimental research.
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ALL engineers and research workers
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MUST VISIT

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FRANCE for the complete documentation, stating if you want it in French, German or English.

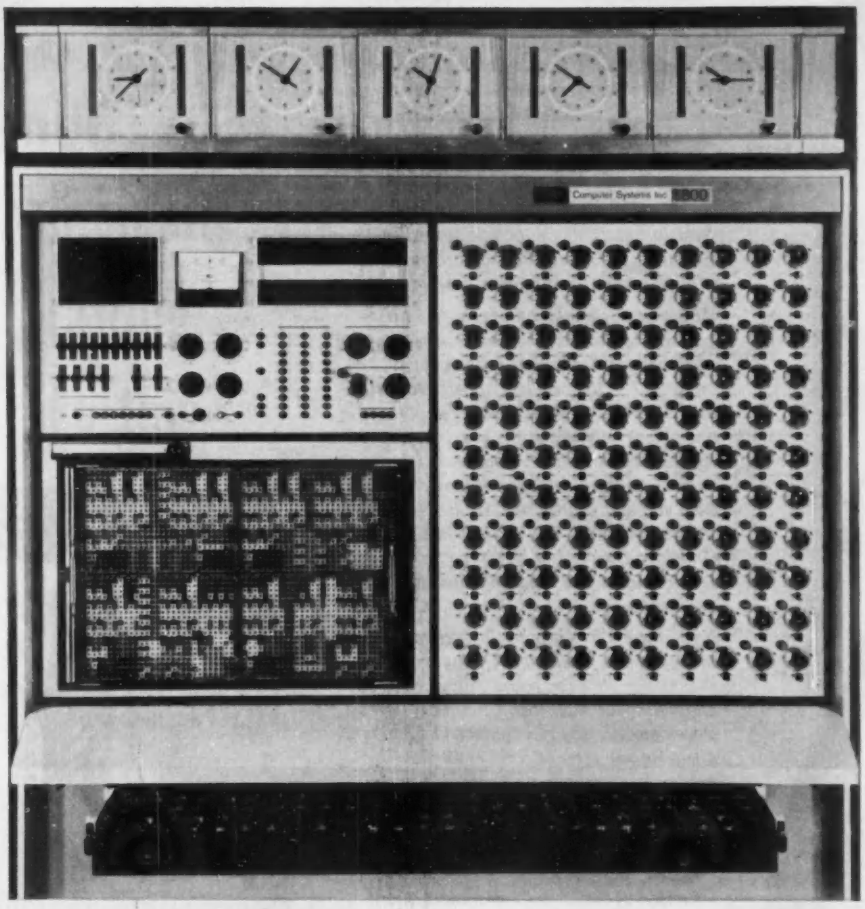
Fourier integrals with parameter variations

$$A(u)\ \text{real} = 2\int_0^1 f(x)\left[\cos\left[(\psi(x)+ux)\right]+\cos\left[(\psi(x)-ux)\right]\right]dx$$

solved in 60 seconds...

$$A(u)\ \text{imaginary} = 2j\int_0^1 f(x)\left[\sin\left[(\psi(x)+ux)\right]+\sin\left[\psi(x)-ux\right]dx\right]$$

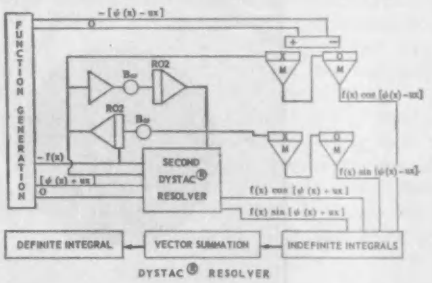
with DYSTAC® 5800 Analog Computer



Chemical process evaluation, microwave antenna design, aircraft and missile design...these are but a few of the parametric studies that DYSTAC, and only DYSTAC, can perform. DYSTAC 5800 is the only analog computer with a memory and high-speed repetitive operations. These two unique capabilities allow the 5800 to make rapid solutions to problems that would otherwise require error-producing over-simplifications.

Unlike other analog equipment, the DYSTAC 5800 utilizes time-sharing of components, thus greatly decreasing the size and cost of the computer relative to its capability. The high-speed rep-ops, together with dynamic storage of analog data, give the machine the best features of analog *and* digital computation. It is the only computer capable of solving equations with two or more independent variables in 60 seconds or less. In addition, it assures data storage accuracies of 0.01% and a time-base accuracy of ±0.5 μsec.

Send for our 11-page report, "Solutions to Bounded Fourier Integrals on the DYSTAC Computer."



DYSTAC® RESOLVER

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Beckman Systems... a world-famous name that stands for the most advanced developments in Electronic Data Processing. Beckman research, study and engineering groups were the first to develop many of today's realistic answers to the ever-increasing demands for reliable, high performance data processing systems. Among them... Multiple Channel Recording, High-Speed Digital Processing, Solid-State Circuitry, and Floating, Low-Level Amplification. Systems applications include space vehicle guidance, automatic plant control, missile ground support and nuclear research.

At Beckman, the difficult problems are our business. Here, the selection of qualified engineers and scientists is as equally important as the problem at hand. In an atmosphere where initiative is encouraged and where achievement is well recognized, top men in the field are your associates in meeting the challenges of tomorrow. Both you and your family will heartily endorse Southern California living. World-renowned Disneyland, beach communities, desert resorts, and mountain areas all are minutes away.

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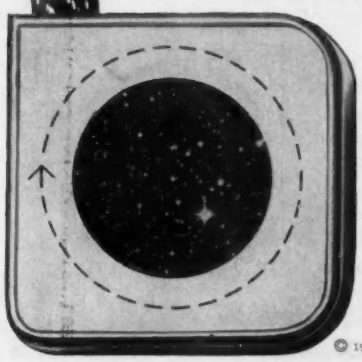

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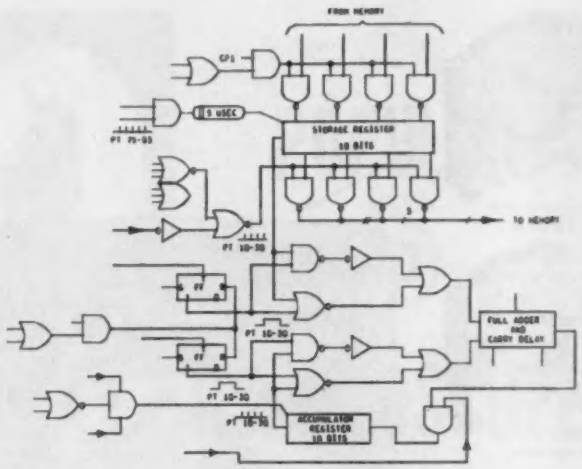
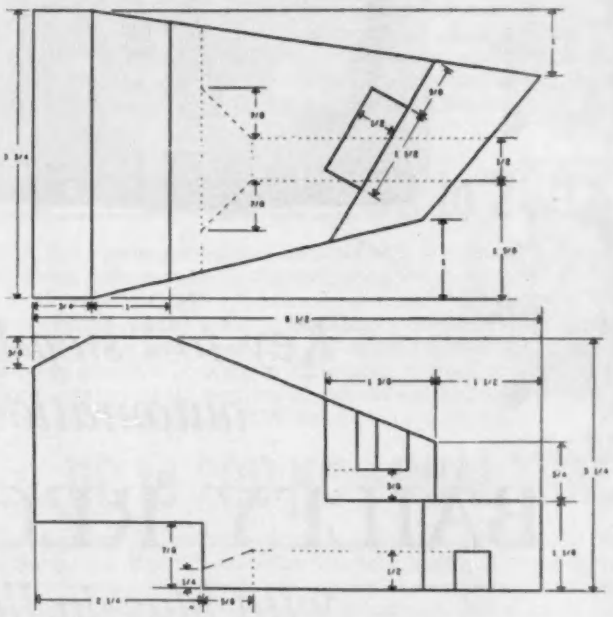
NOW! Automatic drafting like this from your computer in less than 1 second!



Actual drawings produced by the S-C 4020 High-Speed Microfilm Recorder



The S-C 4020

Instantaneous mechanical drawing is now a reality, with the Stromberg-Carlson S-C 4020 High-Speed Microfilm Recorder. Automatic drafting can cut weeks from design time, saving invaluable engineering man-hours. Here's how it works:

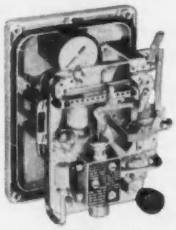
A computer is programmed with the contours and specifications of the part to be designed, using APT (Automatically Programmed Tool) language. The computer operates the S-C 4020 Recorder which makes multi-view mechanical drawings of the part in a fraction of a second. After the drawings have been checked, output of the computer can be used to operate a numerical control tool and produce the part. Capabilities of the S-C 4020 include recording data on microfilm at 17,500 points per second, plotting graphs on microfilm at 12,500 points per second, recording complex logic circuit drawings, tabular printing and forms projection. Write for more details to Stromberg-Carlson-San Diego, Dept. B-13, P. O. Box 2449, San Diego 12, California.

STROMBERG-CARLSON-SAN DIEGO
A DIVISION OF **GENERAL DYNAMICS CORPORATION**

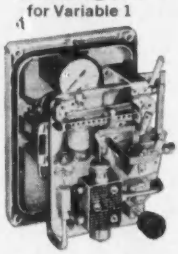
CIRCLE 91 ON READER SERVICE CARD 91

Recording Unit for Variable 1

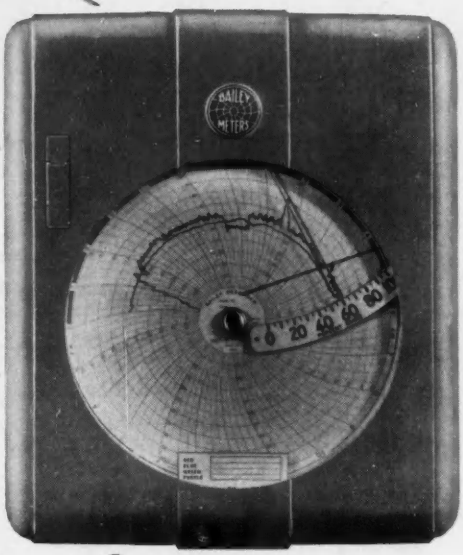
Recording Unit for Variable 2



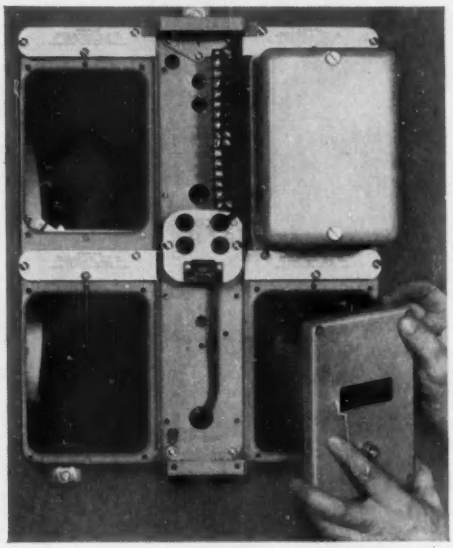
Controlling Unit for Variable 1



Controlling Unit for Variable 2



Back of Bailey Recorder, showing how four plug-in units may be added as needed.



Key to "step-by-step" automation . . .

BAILEY RECORDERS

with plug-in flexibility

When you are pioneering a new process and don't know all the answers, complete automation is seldom practical. The first step is to identify your variables and measure them. Nothing does this job better than a Bailey Recorder. One instrument can record any four variables that can be converted to electric *or* pneumatic signals.

Then you will want to add controls and feed back your measurements. Here's where the versatility of the Bailey Recorder comes into play. For the same Bailey instrument you use to record variables is designed to accommodate plug-in control units.

When you use a Bailey Recorder, you can build your instrumentation along with your process. At the start, you use only the plug-in units for recording. Then you add plug-in controls as you see the need for them.

For the complete story of how you can use a Bailey Recorder for step-by-step automation, contact your local Bailey Engineer.

G154-1

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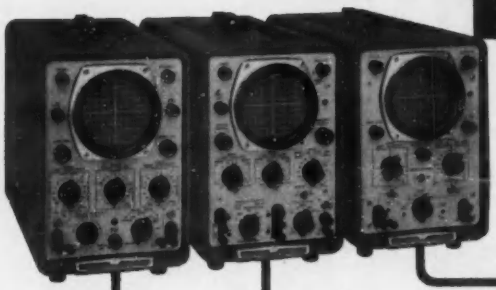

Production or lab instruments—Simple to use, even for non-technical personnel—Moderately priced—Full 10 cm x 10 cm display—Automatic calibration waveforms—Low phase shift—Automatic triggering for optimum presentation—"Times-5" sweep expander magnifies trace, improves resolution.

DC to 200 KC

Models 120A/AR combine minimum controls with hp automatic triggering for utmost speed, convenience. Horizontal amplifier dc to 200 KC; phase shift only ± 2° to 100 KC. More X-axis information due to horizontal amplifier sensitivity control, with vernier, 5% accuracy. Balanced input on most sensitive ranges for low level work. Times-5 sweep expander, all ranges. 15 calibrated sweep speeds, 5 μsec/cm to 0.2 sec/cm. Vernier, expander extend speed range 1 μsec/cm to 0.5 sec/cm. 10 mv/cm sensitivity calibrated vertical amplifier, drift-free trace. hp 120A (cabinet) or hp 120AR (rack), $450.

DC to 200 KC – DUAL TRACE

Models 122A/AR provide simultaneous two-phenomena presentation, are ideal for direct comparison of filter, amplifier output/input phenomena; vibration testing. Unique hp front-panel automatic calibrator waveform switch. Twin vertical amplifiers operate independently, simultaneously, differentially. Automatic triggering, automatic synchronization, single trace operation when desired. Sensitivity 10 mv/cm to 100 v/cm, 15 calibrated sweeps, vernier extension. Horizontal amplifier dc to 200 KC. hp 122A (cabinet) or 122AR (rack), $675.

DC to 300 KC – "BIG SCOPE" PERFORMANCE

Models 130B/BR provide wide usefulness, simple operation and rugged dependability. 21 calibrated sweep times, 1 μsec/cm to 5 sec/cm. Vernier, expander extend range 0.2 μsec/cm to 12.5 sec/cm. Twin horizontal and vertical amplifiers, phase shift ± 1° to 50 KC; sensitivity 1 mv/cm to 125 v/cm. Balanced input on 6 most sensitive ranges. Common mode rejection 40 db. Stability 1 mv/hour after warmup. Triggering automatic, internally, line power, externally, 0.5 v or greater. hp 130B (cabinet) or 130BR (rack), $650.

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Thirteen precision hp oscilloscopes, dc to 1,000 MC

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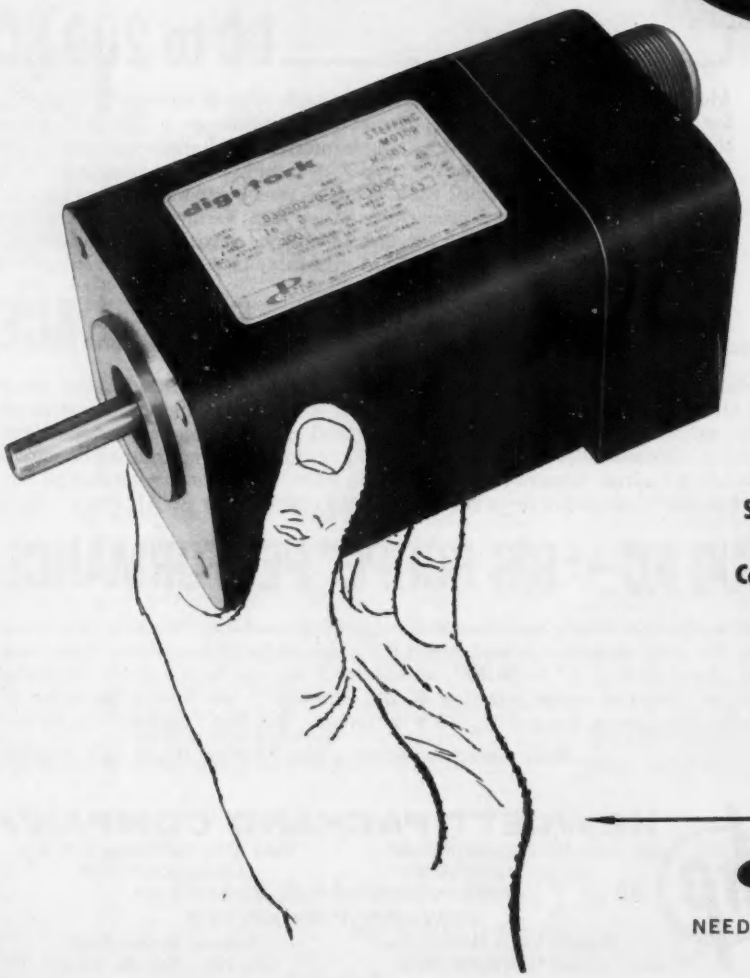
Now! Pace Controls Corp. steps far beyond present limits with DIGITORK, the first completely digital high speed, high torque stepping/actuator to provide precisely controlled discrete increments of motion. Speeds constant over an infinitely variable range. Reversible. Frequency range 0 to 3 kc.

digitork®



FIRST AND ONLY INDUSTRIAL MOTOR OF ITS KIND

Revolutionary in concept, DIGITORK motors are available in sizes from 1 inch ounce to 20 inch pounds. Advanced control systems available, too.

VIRTUALLY UNIVERSAL IN APPLICATIONS

Servo systems • Control actuators
Synchronizers • Variable speed devices
Remote operators, controls, indicators
Computers • Business machines • Pipe line controls • Machine operations
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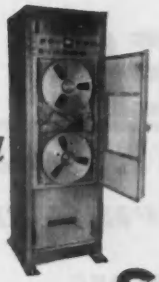
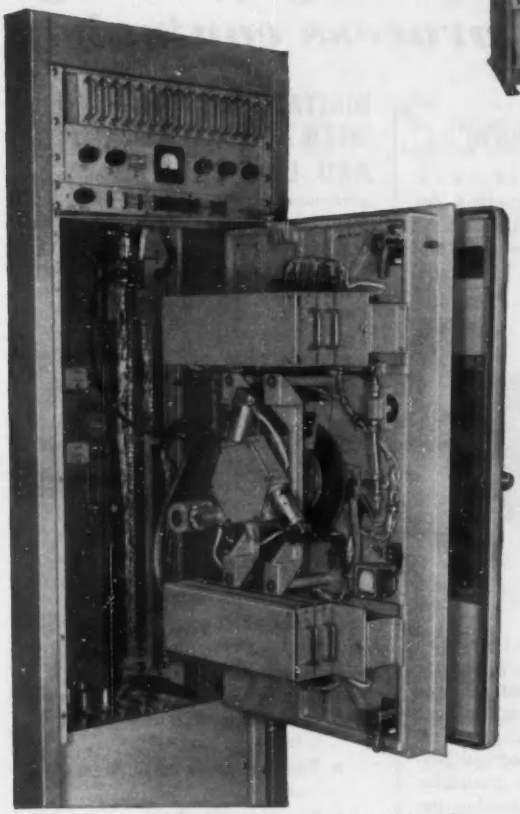
a new concept in speed control





SANGAMO 460-SERIES MAGNETIC TAPE INSTRUMENTATION

Sangamo's Hare Tape Synchronized speed control reduces instantaneous and long term record-playback speed deviations to a level several times lower than other speed control systems. As a result, it is now possible to achieve magnetic tape instrumentation system accuracies heretofore considered unattainable. The Sangamo 460-Series is a fully transistorized magnetic tape Recorder/Reproducer for application in direct analog, wide band FM, PDM, and PCM instrumentation systems.

The Hare Tape Synchronized servo speed control outperforms other servo speed controls in speed of response and range of control. Since a high torque to inertia ratio is designed into the capstan drive, the servo system can respond more rapidly to changes in tape reference signal frequency than drive systems utilizing massive flywheels. For example, an instantaneous change in record tape speed of several percent will be corrected on playback in less than 40 milliseconds. Furthermore, the control is completely damped, eliminating overshoot or the necessity to average the speed. In addition, the Hare servo speed control range is ±15% without loss of synchronism, while conventional tape speed servos have a range of only ±2.5%.

› The Sangamo 460-Series Recorder/Reproducer can instantly be changed from reel to loop operation without rehandling the tape or making any changes in the transport. Exclusive vacuum tensioning and tape guiding provides gentle but firm and precise control of tape position and head-to-tape contact. This design, in addition to a long tape path, results in the extremely low interchannel time displacement error specified. In addition, the vacuum pad removes loose particles from the tape before it passes over the head, thus substantially reducing dropouts and oxide build-up on the head.

› The tape transport and fourteen (14) tracks of Record/Reproduce electronics are contained in a single standard 19" W x 71" H cabinet. This unusual compactness is achieved through transistorized electronic circuitry. The solid state circuitry means greater reliability, reduced weight, lower heat dissipation, and lower power consumption.

For the name of the technically qualified Sangamo representative nearest you, and for complete details on the Sangamo 460-Series, please write for Bulletin 3400.

SANGAMO 460-SERIES
PERFORMANCE and CHARACTERISTICS

Start Time: 1.0 second to synchronism @ 60 ips with servo speed control and 1" wide tape.

Stop Time: 0.2 seconds from 60 ips.

Instantaneous Time Displacement Error: Less than 25.0 microseconds (including flutter) @ 60 ips.

Long Term Time Displacement Error: ±0.01% standard. Higher accuracies available.

Interchannel Time Displacement Error: ±2.0 microseconds @ 60 ips between outside tracks on 1" tape.

Servo Speed Control Range: ±15% nominal tape speed.

Servo Speed Control Response: ±15% speed change per second.

Tape Widths: Standard sizes from ¼ to 2".

Reel Sizes: 14" or smaller.

Mounting: 1 standard 19" equipment rack for a complete 14 track record/reproduce system with power supplies and servo speed control.

Power Requirements: 117 volts, 60 cps ±10% single phase. All D C drives. 7.0 amperes load for 14 track system.

Weight: Approximately 500 pounds for 14 track system.

SANGAMO ELECTRIC COMPANY
SPRINGFIELD, ILLINOIS

ESSM

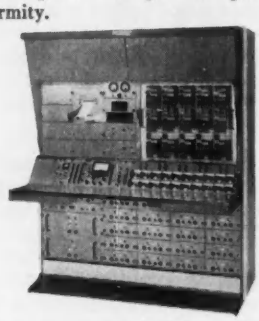
CIRCLE 95 ON READER SERVICE CARD 95

EAI

experience in depth... *computing, plotting, instruments, systems, process control*

ANALOG PROCESS SIMULATION CAN MULTIPLY PROFITS

Extensive process industry experience has proved that EAI Model 231R Analog Computer can make major contributions to profits. Through the use of this versatile analog computer, both in process and controls simulation, optimum utilization of existing plant can be attained. In addition, planned construction can be designed for lowered investment and production costs, improved output and product uniformity.



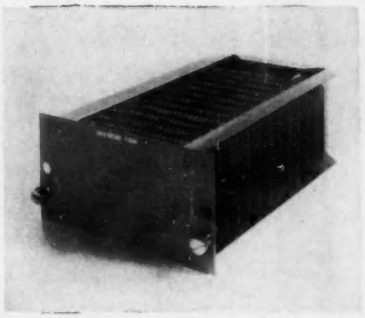
Applications in which EAI Model 231R Analog Computer Systems have proven invaluable include:

- New process research and development
- Process equipment design
- Pilot plant scale-up
- Control system design
- Optimum yield studies
- Chemical kinetic studies

Dozens of EAI analog computer installations are today producing profitable results in process industries. Over 100 problems in process simulation have been solved by EAI Computation Centers for 38 companies in the processing industries. This experience and capability is available to assist you in developing more profitable solutions to your process development and control problems. For complete information on EAI equipment and services, write to Department **11.**

ULTRA FAST AND ACCURATE ELECTRONIC MULTIPLIERS

Part of a new generation of electronic multipliers, designed and developed by EAI, the new Multiplier Model 7.036 combines unusually wide bandwidth with high static accuracy.



Virtually maintenance-free, the Multiplier 7.036 utilizes a unique quarter-square technique that achieves high static multiplying accuracy without the usual resulting deterioration of frequency response. Diode function generators develop the square quantities from x and y imputs, eliminating the need for internal amplifiers.

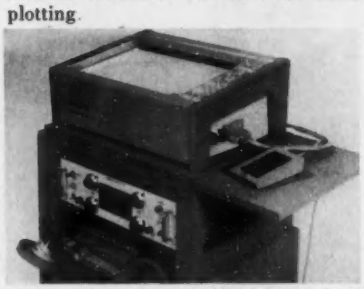
Here are the outstanding features of this new multiplier:

- Outstandingly low output noise—20 millivolts maximum
- Solid state design insures reliable operation
- Holds calibration for extended periods
- Frequency response—over 20 kc
- Static accuracy 0.04%—Zero error 0.01%
- Drift-free, internally temperature-compensated
- Can be added to expand existing systems without modification

For specific details on the EAI Multiplier 7.036, write to Department **12.**

DIGITAL PLOTTING—WITH ACCURACY AND LOW COST

Dramatic improvement in the accuracy of 11 x 17 inch X - Y plots of digital data is now available with EAI Series 3100 DATAPLOTTER. The low cost of this instrument makes available a rapid and economical substitute for laborious hand plotting.



Outstanding features of EAI Series 3100 DATAPLOTTERS include:

- System accuracy up to 0.175% of full scale
- Punched card, tape or keyboard input
- Plotting speeds up to 80 points per minute
- Provisions for "off-board" origin
- Compact, self-contained single cabinet design. Punched card reader external.
- Adaptable to any computer system
- Accepts analog as well as digital inputs

Transistorized control circuitry insures high-speed, accurate, reliable operation. The EAI Series 3100 DATAPLOTTER makes readily available a low-cost tool for fully exploring experimental design problems. It is particularly applicable in data reduction and instrumentation installations. As a management tool, it is valuable for the conversion of computer intelligence to graphic representation of sales, production and cost data.

For details on the Series 3100 DATAPLOTTERS, write to Department **13.**

Career Opportunity for Engineers—Graduate or advanced degrees in EE, Physics, Math—call or write Gordon Strout, Director-Personnel

EAI *See us at Booth Nos. 3712, —14, —16, —18 at the IRE Show, March 20—23*

ELECTRONIC ASSOCIATES, INC. | LONG BRANCH, NEW JERSEY

Computer Scorecard

The year 1960 might well be remembered as the year of the computer. That is the opinion of the Ad Hoc Group* of the AIEE Computing Devices Committee; making special note of the accomplishments of 1960, the committee summarized the year's significant developments during the annual meeting of the AIEE. Said the group, during 1960 the electronic digital computer won its greatest acceptance as a data processing tool (an article in the *Wall Street Journal* reporting that a few EDP installations had to be removed, failed to mention that thousands more had lived up to expectations—11,281 electronic digital computers have been delivered up to Jan. 1, 1961 according to a recent consulting service census), and computers for control moved from speculation to application.

Pointing out that 1960 had seen a flood of new computers, the AIEE group reported that some of these new machines had special significance.

▶Item: Small powerful machines such as the IBM 1401 and the Control Data 160 have launched a technique called satellite computation, in which the small machines do preliminary data processing or subsidiary operations in conjunction with a large machine, thus increasing the efficiency and capability of the larger machine.

▶Item: Stored logic, introduced in the R-W AN/UYK-1, allows a user to impart new characteristics to the computer by reprogramming. In this type of computer the order structure—add, multiply, etc.,—is programmed instead of being wired into the machine.

▶Item: Microwave links and the Data-phone now can link distant points in a single data processing network, leading to greater use of on-line —in contrast to batch—processing.

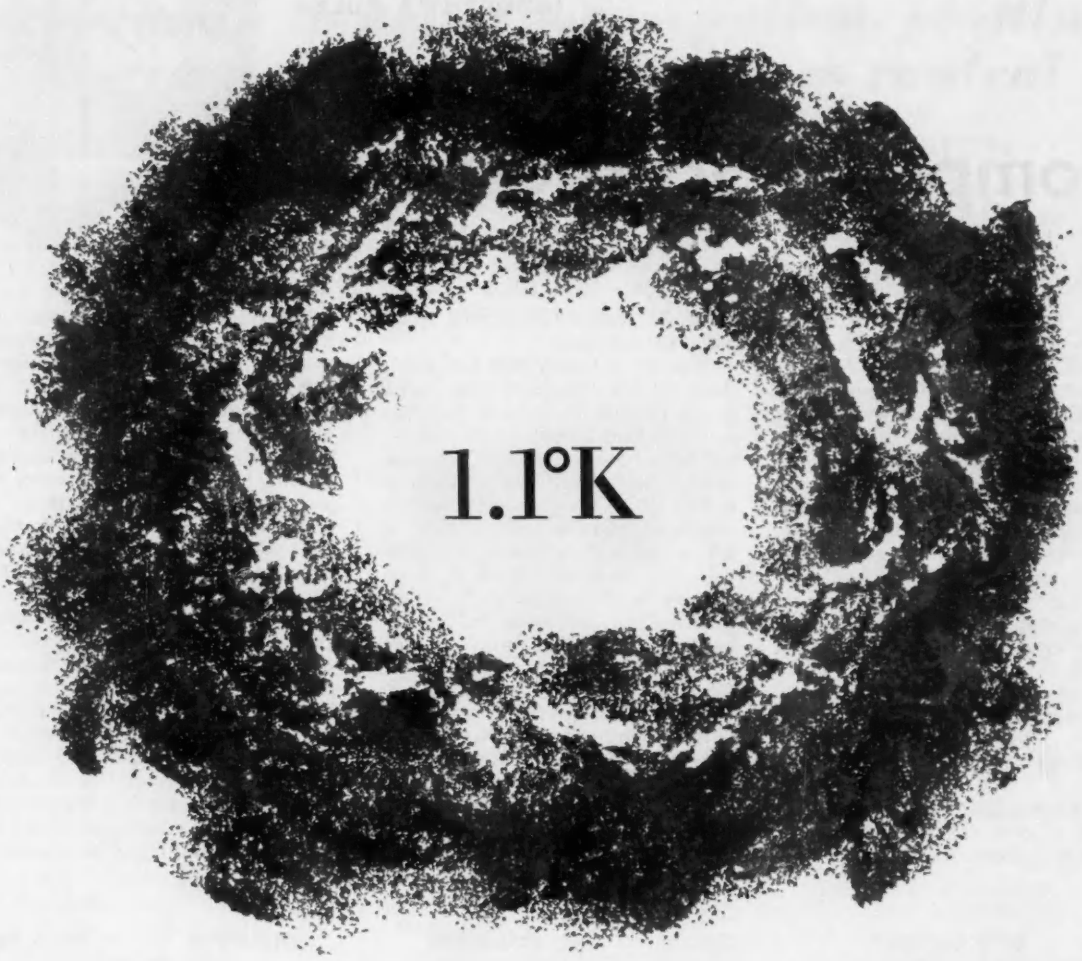
▶Item: A computer designed for process control operated in an electric utility station with an availability of 99 percent, a performance which apparently has established a standard for process control digital machines.

If 1960 is the year of the computer, 1961 shapes up as the year of closed-loop computing-control. CONTROL ENGINEERING editors have prepared a census of closed-loop control applications with digital machines. The tabulation, which deliberately excluded installations whose main purpose is data logging, data accumulation, monitoring, or computation of efficiencies or operating guides, reports 31 closed-loop computing-control applications. A number of installations *not included* in the listing "have provision for closed-loop control". The census:

* *G. L. Hollander, E. Berezin, R. S. Gillelt, L. A. Govid, R. R. Johnson, J. McLeod, D. Ream, and D. L. Stevens.*

DATE ON LINE	USER	COMPUTER	APPLICATION	PROD./R&D
	STEEL INDUSTRY			
1959	**Lukens Steel Coatesville, Pa.**	**GE Direct.[1]**	**Plate mill**	**Prod.**
1960	Youngstown Sheet & Tube Co. Indiana Harbor, Ind.	GE 312	Sintering plant	Prod.
1960	**Jones & Laughlin Steel Co. Aliquippa, Pa.**	**GE 312**	**Continuous annealing line**	**Prod.**
1961	Jones & Laughlin Steel Co. Aliquippa, Pa.	GE 312	Tin plate line	Prod.
1961	**McLouth Steel Co. Detroit, Mich.**	**GE 312**	**Hot strip mill**	**Prod.**
1960	National Steel Corp. Great Lakes Div.	Daystrom Info. Syst.	Hot strip mill	Prod.
1961	**U. S. Steel Gary, Ind.**	**W Prodac**	**Plate mill**	**Prod.**
1961	Republic Steel Gadsen, Ala.	W Prodac	Plate mill	Prod.
1961	**Crucible Steel Midland, Pa.**	**W Prodac**	**Reversing Roughing Mill**	**Prod.**
1961	Jones & Laughlin Steel Co. Aliquippa, Pa.	RCA 110	Tin plate line	Prod.

(Continued on page 99)



Need help in measuring ultra-low temperatures?

A Honeywell transducer now in the works will accurately measure temperatures as low as 1.1° Kelvin. This important new development represents a single concrete result of Honeywell's specialized knowledge of the little-explored world of ultra-low temperatures. Both the knowledge and its implementation are at your disposal, in any degree from basic research to custom design of equipment to your own specifications. If you're now involved with liquid hydrogen, liquid helium, superconductivity of metals—or any project that may call for measurement of temperatures below the range of your present means—Honeywell can help. Write to John Moxness, Minneapolis-Honeywell, 151 E. Hunting Park Avenue, Philadelphia 24, Pa.

Honeywell

First in Control

SINCE 1885

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

DATE ON LINE	USER	COMPUTER	APPLICATION	PROD./R&D
	CHEMICAL & PETROLEUM PROCESSING			
1959	Texaco Port Arthur, Texas	RW-300	Catalytic polymerization unit	Prod.
1960	**Monsanto Chemical Co. Luling, La.**	**RW-300**	**Ammonia synthesis**	**Prod.**
1960	B. F. Goodrich Chemical Co. Calvert City, Ky.	RW-300	Vinyl chloride monomer and Acrylonitrile	Prod.
1960	**Union Carbide Olefins Co. South Charleston, W. Va.**	**RW-300**	**Ethylene oxide, pilot plant**	**R &D**
1960	Union Carbide Olefins Co. Seadrift, Texas	RW-300	Ethylene oxide	Prod.
1961	**Gulf Oil Co. Philadelphia, Pa.**	**RW-300**	**Catalytic cracking unit**	**Prod.**
1961	Celanese Corp. Bishop, Texas	RW-300	Hydrocarbon oxidation process	Prod.
1961	**Dow Chemical Co. Midland, Mich.**	**GE 312**	**Ethylbenzene dehydrogenation to make styrene**	**Prod.**
1961	Tennessee Eastman Kingsport, Tenn.	GE 312	New process in new plant	Prod.
1959	**Universal Oil Products Des Plaines, Ill.**	**Daystrom Flowcon**	**Molex process pilot plant**	**R &D**
1960	Union Carbide Olefins Co. Seadrift, Texas	Daystrom Info. Syst.	Ethylene oxide	Prod.
1959	**Phillips Petroleum Co.[2]**	**Recomp II**	**Thermal cracking furnace**	**R &D**
1961	Standard Oil of Indiana[3] Whiting, Ind.	IBM 1720	Pipe still	Prod.
1961	**Standard Oil of California[3] Richmond, Calif.**	**IBM 1720**	**Fluid catalytic cracking unit**	**Prod.**
1962	E. I. du Pont de Nemours Gibbstown, N. J.	IBM 1720	Acrylonitrile pilot plant	R&D
	UTILITY INDUSTRY			
1961	**Louisiana Power and Light Little Gypsy Station**	**Daystrom Info. Syst.**	**Steam generating plant; automatic startup and shut down**	**Prod.**
1961	Carolina Power and Light Goldsboro Station	Daystrom Info. Syst.	Coal fired generating plant; automatic startup and shut down	Prod.
1961	**Southern California Edison Huntington Beach Station**	**GE 312 (2)**	**Automatic startup and shut down**	**Prod.**
1961	Southern California Edison Alamitos Station	GE 312 (2)	Automatic startup and shut down	Prod.
1962	**Georgia Power McDonough Station**	**GE 412**	**Coal fired generating plant; automatic startup and shut down**	**Prod.**
1961	Gulf State Utilities Riverside Power Station	RCA 110	Peaking plant; automatic startup and shut down	Prod.
1961	**Public Service of New Jersey Sea Warren, N. J.**	**W Prodac**	**Steam generating plant; automatic startup and shut down**	**Prod.**
	FOREIGN			
1960	Badische Anilin-und-Fabrik AG Ludwigshafen am Rhein, Germany	RW 300	Hydrocarbon oxidation process	Prod.
1961	**Electricite de France St. Ouen, France**	**RW 300 (2)**	**High pressure steam generating plant**	**Prod.**

1. GE Directomatic, a special-purpose digital computer.
2. Computer showed way to improve process sufficiently that additional gain with computing-control did not justify expense of computer. Recomp II was returned to its manufacturer.
3. Based on open-loop studies completed in 1960 using an IBM 704 computer.

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Storage Temperature	−65 to +100°C
Collector Voltage, V_{CB}	−20 volts
✓ Collector Voltage, V_{CES}	−20 volts
✓ Collector Current, I_C	−100 ma
Total Device Dissipation at 25°C	60 mw

ELECTRICAL CHARACTERISTICS (T = 25°C)

	Min.	Typ.	Max.	
Static Characteristics				
Collector Cutoff Current, I_{CBO} (V_{CB} = −5v)		1	3	μa
✓ Collector Cutoff Current, I_{CBO} (V_{CB} = −5v, T = 55°C)			18	μa
✓ Collector Breakdown Voltage, BV_{CBO} (I_C = −25 μa)	20			volts
✓ Collector Breakdown Voltage, BV_{CES} (I_{CES} = −25 μa)	20			volts
DC Current Amplification Factor, h_{FE} (V_{CE} = −0.5v, I_C = −40 ma)	20	50		
✓ DC Current Amplification Factor, h_{FE} (V_{CE} = −0.3v, I_C = −10 ma)	30	70		
Base Input Voltage, V_{BE} (I_C = −10 ma, I_B = −1 ma)	0.25	0.32	0.40	volt
Collector Saturation Voltage, V_{CE} (SAT) (I_C = −10 ma, I_B = −1 ma)		0.12	0.20	volt
Collector Saturation Voltage, V_{CE} (SAT) (I_C = −10 ma, I_B = −0.5 ma)		0.15	0.25	volt
✓ Base Input Voltage, V_{BE} (I_C = −10 ma, I_B = −0.5 ma)			0.34	volt
Dynamic Characteristics				
Output Capacitance, C_{ob} (V_{CB} = −6v)		1.5	3	pf
Rise Time, t_r (V_{CC} = −5v, I_C = −10 ma, I_{B1} = −2 ma)		25	60	nsec
Minority Carrier Storage Time Constant, τ_s ($K's$) I_B = −1 ma		100	120	peh/ma
✓ Gain Bandwidth Product, f_T (V_{CE} = −9v, I_C = −5 ma)	100			mc

✓ Checks indicate specification improvements

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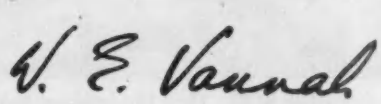
Control
ENGINEERING
MARCH 1961

Duplication Slows Advance

One dispatch after another from McGraw-Hill World News Bureaus brings word that the industrialized countries of the world look to the U.S.A. for advances in control techniques. Yet every visitor who stops in our office on his way home from abroad reports that in individual applications some countries are taking greater advantage of control technology than is the U.S.A. We are told that the most highly automated mail order house is in Nuremberg, Germany. The first automatic subway line runs in London. BASF in Ludwigshaven is a world showplace for advanced process instrumentation, and its chief instrument engineer is a director of the company. The Soviets have started a 2,000-man industrial control application center in Kiev. The total effect of this information on U.S.A. control leaders is deep concern over whether our applied control research is adequate and whether it is coordinated well enough. They begin to speak of a government center for developing control science. They imagine government sponsored advanced control applications that would not have to bear the burden of economic justification.

But if we observe that engineering costs of advanced control systems run equal to or greater than control equipment costs, we are justified in classifying this engineering as applied control research and in deciding that the volume of our applied control research is actually quite large. It is undertaken to gain competitive operating advantage, and it does bear up under economic scrutiny. The problem, then, is neither the amount nor heading of the effort. The problem is the inefficiency of duplicated effort, brought about by commercial and military secrecy.

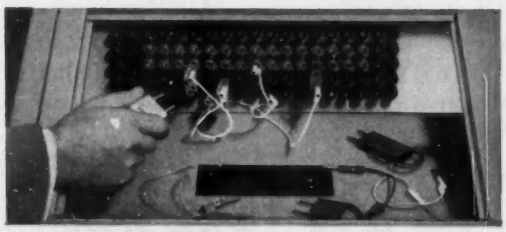
Any reduced duplication would result in increased availability of that rare commodity—advanced systems engineering ability. Insufficient supply of this commodity, rather than of capital funds, is the real cause of slowdowns in adopting advanced automatic systems. User-maker joint effort offers a two-to-one reduction. A user-maker-educator program such as that conducted at Case Institute of Technology since 1954 offers a reduction proportional to the number of industrial organizations that participate. User-maker-government participation, as in the British Iron and Steel Research Association, effects an even greater reduction, but it encounters disagreement on what problems to tackle. Choose your method; each works to some degree. But the only completely effective method is for the eventual users to freely disseminate the knowledge they gain in applying advanced systems engineering.



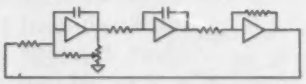
Did you ever use a computer as versatile as the DONNER 3100?

The Donner 3100 isn't for people who merely wish to push buttons. It is a medium sized, high accuracy computer, simple to operate, but designed so it doesn't horsecollar the operator. In its class (20 to 100 amplifiers) it is the most versatile analog computer. Two big reasons for this are the 3100's *uncommitted amplifiers* and its *simulation board*, an auxiliary patchbay electrically connected to the main removable problem board. Here's what they do:

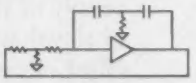
Uncommitted Amplifiers. The 3100's amplifiers are not already wired as summers or integrators. The operator patches his resistors and capacitors to the amplifier. Obviously, he is not limited to using computing components with fixed values. If he wants to use only two components per amplifier, all the rest are free. Depending upon your needs, the 3100 can be supplied with up to 50 amplifiers per console and two or more consoles may be slaved.



The Simulation Board. Here the operator can plug in a wide variety of components—resistors, capacitors, pots and diodes. He can synthesize (a) complex input and feedback networks for amplifiers, (b) complex resistor-diode limiting circuits and (c) resistor-capacitor-inductor filter networks. Programming these circuits on the simulation board is far simpler and saves amplifiers. For example, a mass-spring system is oscillatory and usually needs three amplifiers to simulate it:



But this clever little circuit does the same thing:



You see, we have eliminated two amplifiers by using the simulation board.

Speaking of economy, **$13,995** buys a Donner 3100 with 30 stabilized amplifiers and 55 potentiometers. A full line of nonlinear and accessory equipment is available. Free instruction on computer theory and operation is included.

Get More Facts — *Contact your Donner engineering representative for Data File 310, or write directly to Dept. 21.*

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A
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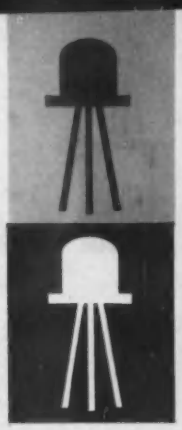
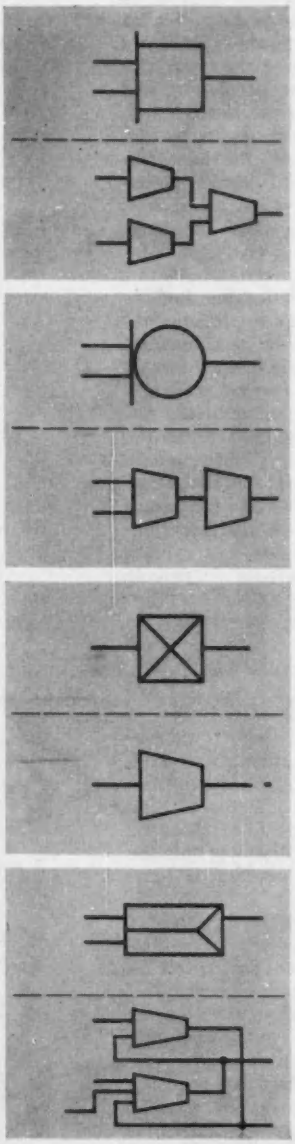




Transistor Switches for Industrial Service

Transistors make excellent low powered switches —they are small, fast, reliable, and not too expensive. And recently several manufacturers have developed lines of transistorized logic packages for industrial environments, so that system application is mainly a question of logical design and not of electronic circuit design. The transistor itself need concern you no more than a contact on a hermetically sealed relay. Static output amplifiers using power transistors or silicon controlled rectifiers are also becoming available at a reasonable price. To keep you abreast of this rapidly moving field this report tells how transistors perform logic functions, looks at available systems and components, gives tips on selection and use, and shows case studies of transistor logic at work in industry.

JOHN C. STURMAN
Lewis Research Center
National Aeronautics and Space Administration

Transistors used as switches can perform the same logic functions as electromechanical relays or static magnetic logic elements. The term "logic function" refers to the elements AND, OR, NOT, and NOR as well as switching, programming, and interlocking functions between the inputs and outputs of a control system. These latter functions are actually combinations of the basic formal logic elements, although in many cases they need not be considered as such for purposes of system design.

Although transistor logic has a number of advantages over other devices, its value is not just as a replacement for or improvement over older-type devices in existing applications. Rather its real worth lies in the control applications now made possible by its use. As such, industrial transistor switches add a new tool with which the control engineer must become familiar if he is to design the optimum control system for a given application.

Electromechanical relays have the advantages of being relatively inexpensive, readily available in numerous varieties, capable of providing sufficient power to drive most output devices directly, and operable without special power supplies. Because of their widespread use, designers are familiar with their application and service personnel with their maintenance and repair. On the other hand, industrial control relays are fairly large, slow, and require several watts of power. For many small to medium sized industrial applications these disadvantages are negligible: the most serious drawback is usually reliability. Relays, being mechanical devices, have a life that depends on the number of operations. While relay manufacturers claim lives measured in millions of operations, this figure may be drastically reduced in contaminated, dust laden, or corrosive atmospheres unless the relay is of the hermetically sealed (and more expensive) variety. Also, in high speed repetitive applications even a 10-million cycle life may be completely inadequate. Thus electromechanical relays seem best suited to the smaller, less critical application, particularly where the number of output devices such as solenoids and starters is large compared to the amount of logic.

Static magnetic switching devices, such as Cypack (Westinghouse Electric Corp.), are special types of magnetic amplifiers designed for switching service (Ref. 1). As the name implies, they contain no moving parts and can therefore be potted or encapsulated in a solid plastic block. This results in a unit that is physically rugged, extremely reliable, and completely insensitive to environment, and that requires essentially no maintenance. Life is independent of the number of operations and is estimated by one manufacturer to be 30 years. Size, weight, and speed of operation are all roughly comparable to electromechanical relays.

The first cost of a static magnetic system is usually considerably greater than the equivalent relay system. One reason for this is the high cost of output amplifiers necessary to raise the low power output of the logic elements to a sufficiently high level to drive most industrial-type output devices. Special input converters and power supplies are also necessary. Total system cost is therefore influenced to a large extent by the number of outputs as compared to the number of logic units. Cost has been the major factor limiting the popularity of static magnetic switches.

Transistor switching elements have all the advantages of static magnetic devices and, in addition, are much faster, considerably smaller and lighter, and use very little power (therefore requiring no cooling). These characteristics allow not only the replacement of relays and static magnetic devices, but also the construction of completely new and different types of control systems not hitherto possible. While the application of transistors to industrial control is too new to have demonstrated long term reliability, past experience in computers, missiles, and other military systems shows conclusively that very long life and high reliability are possible.

Disadvantages of transistor switching include the need for special power supplies and output amplifiers. Cost will in many cases be somewhat more than for corresponding relay systems if they exist; however, since many control problems can be solved in new and better ways, often the comparison of first costs may not be truly valid.

A number of lines of transistor logic elements are available as off-the-shelf items. Of the group intended specifically for industrial switching applications, some are available as modular components so that the user can do his own system design, while others are only available as systems engineered to user specifications by the supplier. Another group consists of computer-type logic modules. Although originally intended for breadboarding and special purpose computers, many systems using computer-type modules are now being used on the factory floor.

With these two groups of transistor logic elements it is possible to construct nearly any kind of digital control system imaginable, although if it can be built with relays the transistor version may be more expensive. As a guide to the type of application where transistor logic should be used to replace relays, one manufacturer uses the following requirements:

1) ratio of inputs to outputs must be greater than 5 to 1

2) ratio of control relays to outputs must be greater than 5 to 1

3) must have at least 50 relay contacts in the circuit that are not directly controlling outputs (solenoid valves, starters, clutches).

If a proposed control system meets these requirements, the transistorized version should be competitive with the equivalent relay system on a first cost basis. If speed or reliability are important, they must be added to the above considerations in determining the relative desirability of transistor logic. In many cases it is these latter considerations that are deciding factors in favor of transistor logic.

HOW TRANSISTORS PERFORM LOGIC FUNCTIONS

An ideal logic element should be able to accept several inputs while providing an output capable of driving a number of similar elements without intermediate amplification. Transistor switching circuits are nearly ideal in this respect. The circuits shown here use PNP transistors. While this is typical of available logic elements, all circuits can be and are used with NPN transistors by reversing the polarity of all voltages and diodes. Of the possible transistor circuit configurations only the common emitter circuit can provide both current and voltage gain. It is this characteristic that makes possible transistor-resistor logic (TRL) using only transistors and resistors. TRL circuitry is both simple and economical although it is not as fast as some of the refined approaches.

The simplest TRL element is the inverter or NOT circuit, Figure 1A. As shown in Figure 1B, the transistor volt-ampere characteristics can be divided into three distinct regions of operation. In region *a*, the area below the zero base-current line, the transistor is cut off. It has nearly the full supply voltage across it and acts essentially as an open switch or relay contact. The effect of the small leakage current that does flow in the transistor can be made negligible by proper circuit design. Region *b* is the active portion in which the transistor acts as a continuous amplifier. Operation in region *b* is not permitted in switching applications except during the switching transient. In region *c* the transistor is in saturation: there is little voltage drop across it and the current is limited by the external circuit resistance. This state corresponds directly to a closed switch or relay contact.

Neglecting the effect of R_2 in Figure 1A and grounding the input (logic 0 input), the operating point will be on the load line at its intersection with the zero base-current curve. Output is very nearly supply voltage as seen through R_3 (logic 1 output). In this condition the current that flows is due to transistor leakage. And since this current increases rapidly with temperature it is necessary to supply a small reverse bias current through R_2. Reverse biasing the base-emitter junction by a fraction of a volt is sufficient to force the operating point well into region *a*, decreasing the leakage current to nearly zero, and stabilizing operation at high temperatures. Since only a small reverse bias is required R_2 can be made large compared to the input resistance R_1 so that it will not appreciably affect the input.

The value of R_1 is such that when the input is

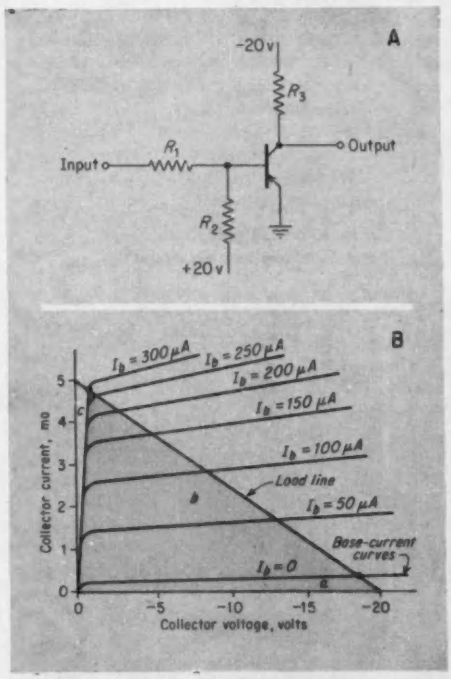


FIG. 1. Basic transistor NOT or inverter circuit, A, and typical transistor voltage-current characteristics, B.

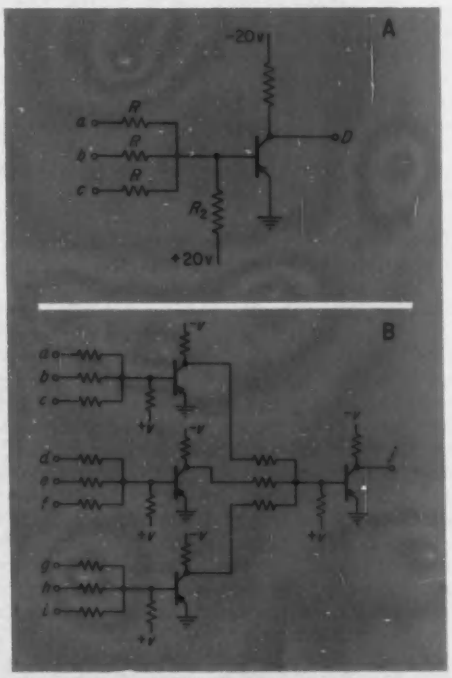


FIG. 2 The popular NOR circuit, A, and implementation of AND function using NOR elements, B.

driven negative by a 1 output from a similar preceding stage, sufficient current will flow in the base to drive the transistor into saturation. The operating point will then be on the load line within region c and near the boundary between regions b and c, and the output will near ground potential (logic 0 output). This circuit is an inverter or English logic NOT: nearly all switching circuits can be derived from it.

The addition of several input resistors to the basic inverter circuit gives a circuit, Figure 2A, that will have an output (negative voltage) only when there is no input at a NOR b NOR c. This is the NOR circuit for which the Boolean algebra expression is

$$d = \overline{a + b + c}$$

corresponding to an OR followed by an inverter. If the biasing resistor R_2 is chosen so that a signal (logic 1) must be present at each input before the transistor turns on, then a type of AND circuit with inverted output results.

Of these basic circuits the transistor NOR is the most universal. Used with only one input it fulfills an inverter or NOT function. Cascading a NOR and a NOT gives the exact equivalent of the English OR, and interconnecting NOR's as in Figure 2B results in an exact equivalent of an AND. If only one input of each input NOR is used, the circuit becomes an exact three-input AND. If all inputs are included the circuit corresponds to the Boolean expression

$$j = (a + b + c) \cdot (d + e + f) \cdot (g + h + i)$$

which represents three three-input OR gates with their outputs ANDed together. It is now apparent that any logic circuit can be built up with only the single NOR element; however, it would seem that more elements would be required than in the corresponding English logic circuit because of the undesirable inversions. This is usually not the case, since by changing the functions slightly and eliminating double inversions one can get rid of the additional elements.

While the transistor NOR circuit would seem to be the simplest, cheapest, and therefore the best for most applications, it does have the disadvantage of being relatively slow. Since the input is through a fairly large resistor, the RC time constant of this resistor and the transistor input capacitance can limit turn-on time, while turn-off time is limited by minority carrier storage within the transistor. Thus the maximum switching speed is about 25,000 operations per sec for medium speed transistors. This is certainly fast enough for many industrial applications, but not for some that use techniques borrowed from digital computers.

Faster operation may be achieved either with better and therefore more expensive transistors

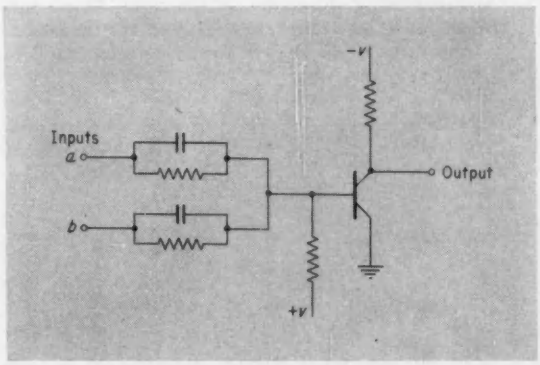
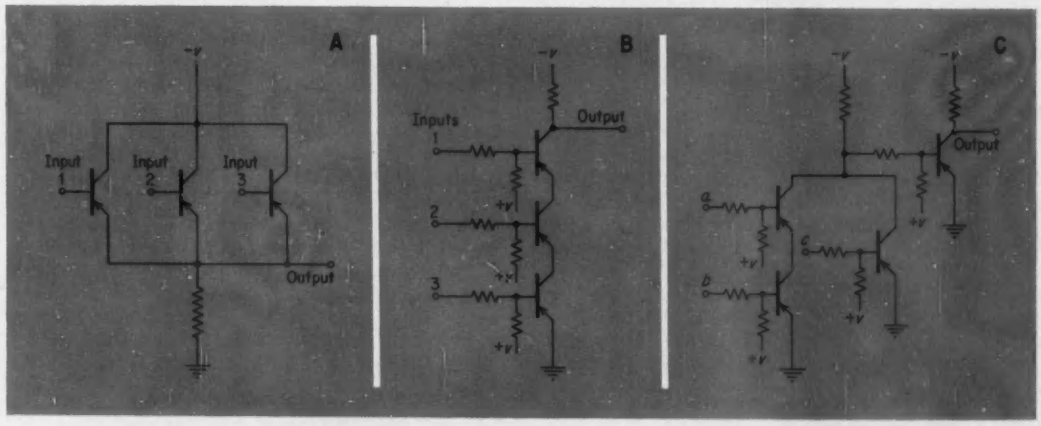


FIG. 3. Capacitors across the input resistors will speed up the NOR circuit.

FIG. 4. Typical transistor gates: A shows an OR gate, B an inverting AND, and C a combination AND-OR gate.



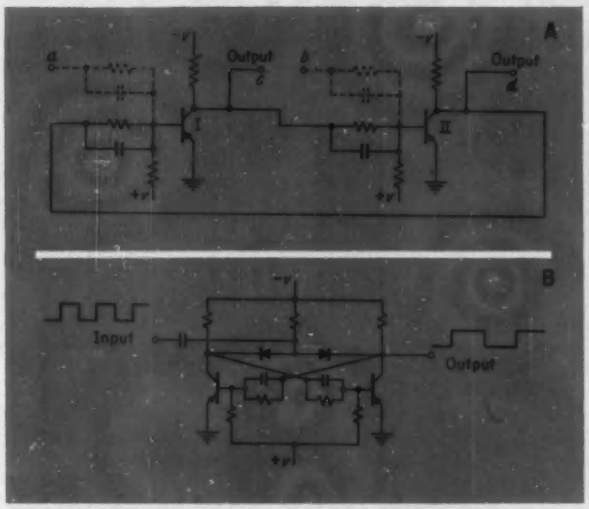


FIG. 5. Flip-flop, A, is basic element that can be used to form more complex elements such as binary counter, B.

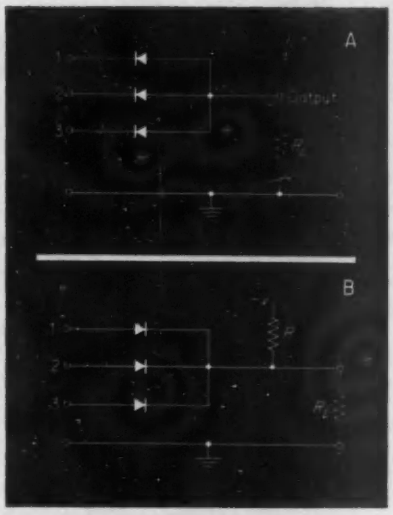


FIG. 6. Diode OR gate, A, AND gate, B.

or by using a "speed-up" capacitor across each input resistor as shown in Figure 3. This permits the transistor to be heavily overdriven at the start of the switching cycle, thus reducing switching time. Logic networks using a speed-up capacitor form a class of circuits called resistor-capacitor-transistor logic (RCTL).

One method of achieving still higher speeds is to use nonsaturating circuitry. This eliminates the heavy buildup of minority carriers in the transistor junction associated with saturation, and thereby speeds up switching. Because nonsaturating circuitry is considerably more complicated and is more critical of components and operation, its use has been primarily in high speed computers and will probably not be extended to industrial applications. Even the majority of high speed computer-type packaged logic elements do not use nonsaturating circuitry.

Computer-type circuits

A second general class of circuits is those found in digital computers. These include flip-flops, shift registers, one shot multivibrators, blocking oscillators, transistor gates, emitter followers, and others. Since none of these circuits is particularly new, and all are extensively covered in the literature (Refs. 2, 3, 4), the treatment here will be limited to that necessary for a minimum understanding of their functions.

Transistor gates fulfill the logic functions AND and OR or combinations thereof. Figure 4A shows a three-transistor OR gate. Using the previous convention letting 0 equal ground potential and 1 a negative voltage, a 1 at any input will cause that transistor to conduct, producing a 1 output. This circuit is actually three emitter followers with a common load. Since the output of an emitter follower is always a fraction of a volt less than the input, cascading is limited. Although a similar AND circuit is possible, the one shown in Figure 4B is usually preferred. Amplification is provided, but since the transistor acts as an inverter an output 0 is obtained for a 1 at each input.

How more complicated functions can be synthesized with this type of circuitry is shown in Figure 4C. This circuit is a combination AND-OR gate that fulfills the logic expression Output $= (a \cdot b) + c$; a 1 output is produced when (a AND b) OR c is a 1. Transistor gating is very flexible and is capable of operation in the megacycle range. Disadvantages include stringent requirements on the transistors for use in series circuits such as Figure 4B and the need for one transistor per input.

Blocking oscillators, pulse amplifiers, and one shot multivibrators are often used as pulse shaping circuits. They can accept a pulse that has been degraded both in level and rise time and put out a clean sharp pulse of standard size. Pulse amplifiers, blocking oscillators, and emitter followers are also used as intermediate stages when driving many loads or for isolation.

One of the more important and widely used circuits is the flip-flop or bistable multivibrator. It can be considered as two inverter circuits in series, with the output of the second brought back to the input of the first, Figure 5A. If transistor I is conducting, its output will be near ground (0) and transistor II will be cut off. The output of II will therefore be a 1 as required for the input to transistor I. This stable state will be maintained unless an external signal is introduced or the power is turned off. A second distinct stable state is possible with transistor I cut off and transistor II conducting.

By adding another input to each transistor (dotted lines in Figure 5A) a storage element is obtained. The circuit then essentially con-

sists of two NOR's and is, in fact, a practical method of creating a nonretentive storage element in systems using primarily NOR elements. If a 1 input is applied to input *a*, transistor I will saturate, producing a 1 output at *d* which will remain even after the input is removed. Likewise, an input at *b* will produce an output at *c*. A 1 at one of the outputs designates a set condition, at the other output a reset condition. If a retentive memory function is required, the usual practice is to use a small magnetic core to provide storage whether or not power is applied and to insure that the flip-flop returns to the proper state after a loss of power.

The divide-by-two circuit of Figure 5B consists of a flip-flop plus steering diodes and an input capacitor. For each two positive input pulses one output pulse is obtained. By cascading these elements it is possible to construct a counter, each stage of which will divide by two. The total capacity of the counter is 2^n where n is the number of stages.

The shift register is another type circuit based on the flip-flop. It consists of a chain of flip-flops connected together by coupling networks that transfer the information stored in each stage to the following one in the chain when a command pulse is applied to each stage. Information may be set into the first stage in serial fashion, each bit being shifted along one place as the next one is introduced. In this manner it is possible to store a record of various events in the order in which they happened. A serial pulse train can also be fed in and read out simultaneously from each stage in parallel form, or vice versa.

Diode circuits

One of the simplest means of obtaining AND and OR logic functions is by the use of diode circuits. A negative voltage applied to any of the three inputs of the diode OR circuit in Figure 6A will produce an identical output except for a few tenths of a volt drop across the diode. Since the path between any two inputs is through one diode in the forward direction and one in the reverse direction, the inputs are effectively isolated regardless of signal polarity. This is important where a gate has many inputs. The transistor NOR circuit, for example, can use only a limited number of inputs because of the shunting effects of the inputs that are tied to ground. In contrast, presently available diodes have back

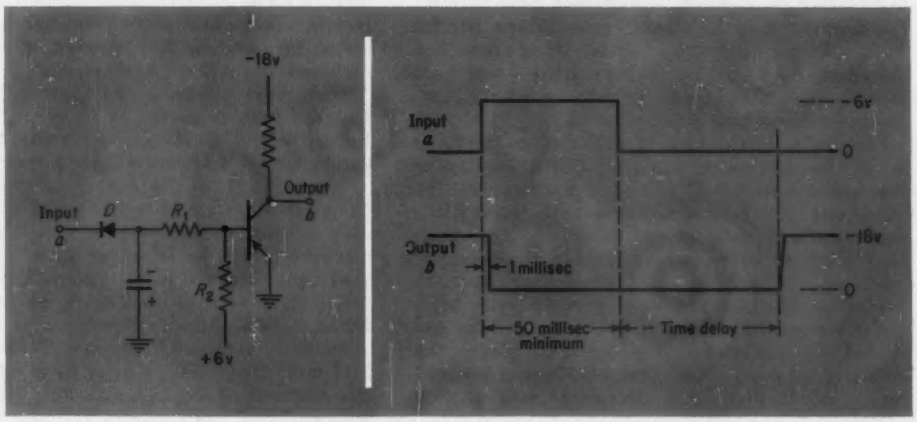


FIG. 7. Time delay element, A, and its voltage-time characteristics, B.

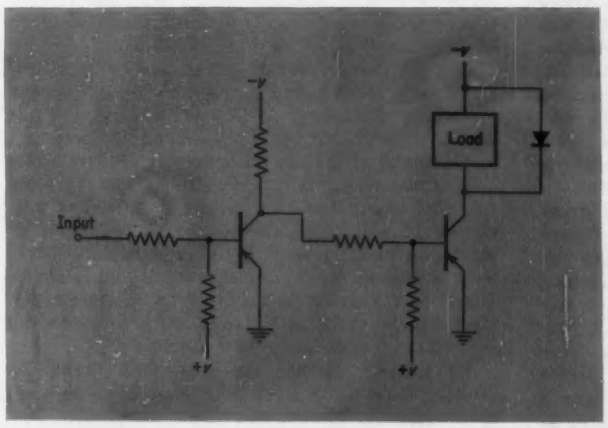
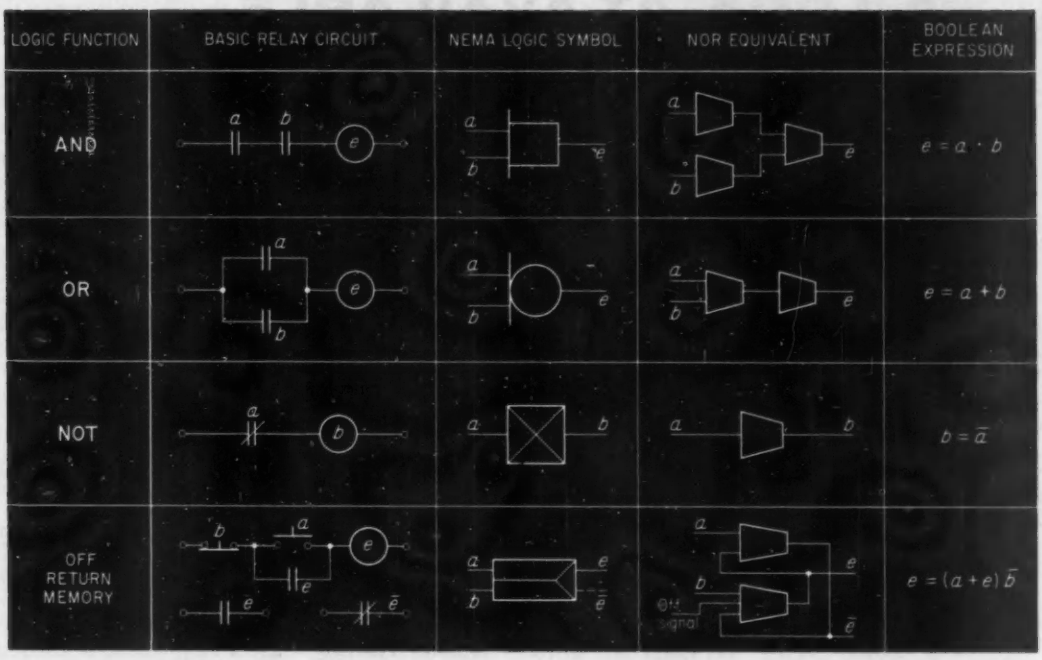


FIG. 8. Two stage transistorized output power amplifier.

FIG. 9. LOGIC SYMBOLS COMPARED.



resistances sufficiently high to handle as many inputs as are normally required.

The AND function can be implemented with diodes in a similar fashion, Figure 6B. If any of the inputs are at ground potential, there will be a conducting path present from the negative power supply through that input diode to ground. The output is then a forward drop across the diode or essentially ground. This circuit requires that inputs in the 0 state present a low impedance to ground as in most transistor circuits. If all the inputs go negative (logic 1 input) the output will be unclamped from ground and will become equal to the input.

Since there is neither voltage nor power gain in diode logic it is seldom practical to cascade more than one or two stages without amplification. In practice a diode gate is usually fed directly into a NOR, inverter, or other form of amplifier.

Time delay circuits

Many control applications require time delays that can be provided by a circuit such as shown in Figure 7A. If initially the input a is at ground potential and the capacitor is discharged, then the transistor is cut off and there is an output at b. Applying a negative signal to the input will start the capacitor charging and in approximately 1 millisec the voltage from emitter to base will be sufficient to saturate the transistor, driving the output to zero. If the input now goes to zero, the capacitor cannot discharge through the input because diode D blocks current flow in this direction. It must discharge through the combination R_1, R_2, and the transistor. Since only a small voltage is required to keep the transistor conducting the output will be zero until the capacitor is nearly completely discharged.

The input and output voltages as a function of time are shown in Figure 7B. Time delay can be varied by changing the size of either the capacitor or R_2. The circuit is useful over a range of about 50 millisec to several seconds.

Power amplifiers

Some form of power amplification is necessary since the internal power level in transistor or diode logic circuits is too low to drive industrial output devices directly. The typical transistor power amplifier of Figure 8 uses two basic inverter circuits to provide a large power gain with no signal inversion. The first stage transistor can be a medium power device, while the second one must be a power transistor capable of switching the full load current. A diode is often used across an inductive load such as a starter coil to prevent a high voltage transient across the load when current is cut off. Such a voltage spike might permanently damage the transistor if it were not suppressed. Suppression of relay and starter coils with a diode may increase their drop-out times to as much as a tenth of a second or so. If this is critical other means of suppression may be necessary.

The summary of Figure 9 shows some of the basic logic circuits discussed above with their NOR and relay equivalents, and Boolean algebra expressions. The symbols used are predominantly those adopted by the National Electrical Manufacturers Association.

A LOOK AT AVAILABLE SYSTEMS AND COMPONENTS

There is a large number of manufacturers producing semiconductor logic elements and systems. These divide into two broad classes—industrial and computer types—the distinction being made on the basis of intended application since there is an overlap in both circuitry and packaging.

In general, the industrial-type element is somewhat more ruggedly packaged and tends toward simpler circuitry, such as the NOR. Four companies now produce this type of device. This situation may well change in the near future, however, since apparently other companies are readying similar systems.

So far the majority of transistor logic elements suitable for industrial application use germanium PNP transistors. The choice is mainly one of cost and availability. PNP units are more plentiful than NPN and have generally better characteristics for a given cost. The maximum ambient temperature for germanium transistor circuits is usually within the range 55 to 75 deg C, depending on circuit design and packaging. One typical industrial line is rated 0 to 60 deg C which should be sufficient for most industrial applications. Silicon transistors—at present used by only one manufacturer of industrial type logic—extend the upper temperature limit to about 100 deg C (Ref. 5). While they offer better high temperature performance, the cost of silicon transistors is from two to four times that of comparable germanium units. There are a few computer-type silicon transistor logic elements available.

Square D Co.

Square D was the first company to introduce industrial logic components on a do-it-yourself basis. They feel that their approach is simple enough for anyone familiar with industrial control systems, but, in addition, have a number of trained specialists both in their field organization and at their headquarters who can assist in application problems. Square D will also do the systems engineering and/or supply the system.

As the name Norpak implies, the NOR circuit is the basic Square D logic element—simplifying the design and construction of control systems. Typical Norpak system units shown in Figure 10 are designed to operate over the temperature range 0 to 60 deg C, and are color coded for identification. The red module in each unit is the bus module and energizes all logic modules in that pack when connected to the power source.

Units are supplied as multiple circuits potted in epoxy resin. They can be mounted directly on a panel with the necessary power supply and other components to form a compact assembly. Input, output, and power connections are on taper pin terminals on the front of the module, so that wiring is done with precut jumper wires with taper pins at each end. The leads may be removed by twisting, after which they can be reused. The simplicity of this method is claimed to reduce wiring cost by as much as 80 percent.

Norpak units contain six (occupies 7½ sq. in.) and 20 (occupies 18 sq in.) NOR circuits each. They are white and have one red bus module. Each NOR circuit will accept three inputs and drive four outputs. Where it is necessary to drive more than four outputs, two NOR's can have their inputs paralleled and the load split between them, or a universal power NOR can be used. The latter (blue colored) can drive up to 10 outputs or a light relay load.

While the NOR can perform all logic functions except retentive memory and timing by itself, circuit simplifications can sometimes be achieved by using diode OR circuits. Square D provides a yellow-coded package which contains seven silicon diode OR circuits, each circuit consisting of one two-input diode and one one-input bypass diode. Small neon lamps permit visual monitoring of the states of logic elements. These lights

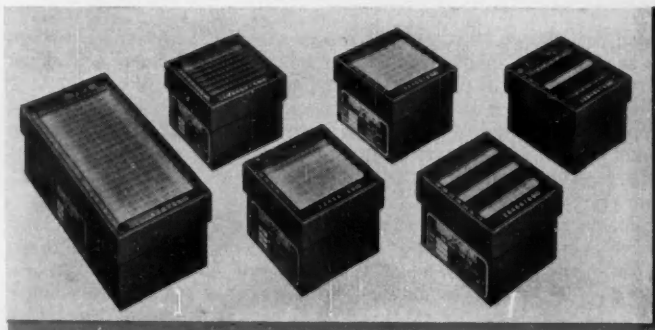


FIG. 10. Units comprising Square D Norpak system.

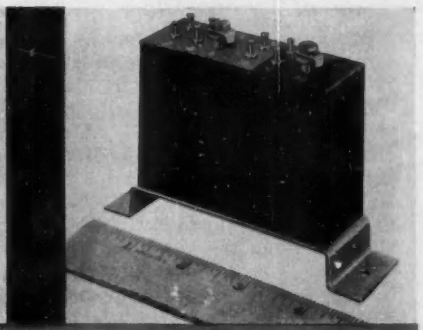


FIG. 11. 30-watt transistorized power amplifier available from Square D.

can be connected directly to the output of any NOR without decreasing its output capacity. A special power supply will handle up to 50 lights.

In addition to these basic logic elements, Square D offers a Time Delay Pak and a Retentive Memory. The time delay, identified by gray coding, consists of one adjustable timer encapsulated in a standard package. It provides an adjustable timing period of from 0.05 to 9 sec nominal. Repeat accuracy is within plus or minus 5 percent and reset time is under 10 millisec. For applications requiring a memory function that is unaffected by power failures, a package containing a single retentive memory is available. It returns to its previous state after power is lost and restored.

Logic element output is amplified by transistor power amplifiers or by transistor-relay amplifiers. Completely static amplifiers, Figure 11, are to be preferred for applications requiring the utmost in reliability. They deliver power at 24 vdc and are available in a 5 watt size for small solenoids and incandescent pilot lights and in a 30 watt size for larger valves, clutches, and motor starters. Transistor-relay amplifiers come with SPDT or DPDT output contacts rated at 10 amps, 300 volts (75 percent power factor). The relays are the hermetically sealed plug-in type.

Input to the Norpak system can be from conventional pushbuttons, limit switches, or even relays. The logic power supply provides 130 vdc to the input device to eliminate the problems associated with reliable switching of low voltages. The 130 volt output is then attenuated by a dc signal converter to a level compatible with the transistorized logic. Should the input device provide a 115 vac signal, an ac converter consisting of a small transformer and rectifier can be provided to convert the input into the 20 vdc signal required by the Norpak elements.

General Electric Co.

General Electric designed and engineered its line of transistorized logic for the user who wants to purchase a complete control system. Marketed under the name Directo-Matic* by the Industry Control Dept., Salem, Va., it made its appearance about two years ago. Although one of the principal components of Directo-Matic is its transistorized digital logic, it is more than just a logic system. It is a completely integrated line of static control devices engineered to provide maximum reliability under adverse industrial environments. The system includes both digital and analog transistorized control units, semiconductor and magnetic amplifier output amplifiers, wiring, and enclosures.

The primary logic element in this system is the NOR; however, a complete line of more sophisticated circuits such as counters, shift registers, code converters, and pulse generators is also available. Universal logic elements (NOR's) are made in three speeds, the fastest of which operates at a 500 kc rate. Each universal logic element package contains two two-input and two four-input NOR's, each NOR requiring a minimum input signal of 1.4 milliamps which is defined as "one load". Each output can drive a maximum of eight loads. To complement the NOR logic several diode AND and OR elements are available. One contains two two-input OR's and two four-input OR's, while another has two two-input and two three-input AND's. In all cases it is possible to tie the outputs of several diode circuits together to provide more inputs.

* Trademark of General Electric Co.

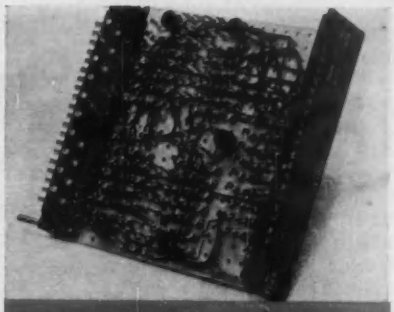


FIG. 12. General Electric Directo-Matic logic element with cover removed.

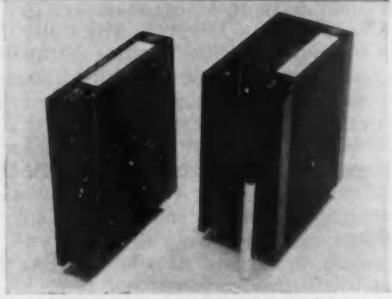


FIG. 13. GE logic elements are available in two case sizes.

All logic units are of open construction on terminal boards using wire-wrap connections, Figure 12. Striking testimony to the reliability of this method is that to date not a failure has occurred that could be attributed to a faulty wire-wrap connection. Protection against moisture and corrosive atmospheres is provided by a thin conformal coating of a special clear plastic compound, completely sealing all components but allowing for replacement if necessary. In addition each element has a plastic cover.

The basic element is approximately 5 in. wide, 6 in. high, and 1½ in. deep, and weighs about 1 lb. Where large components are necessary a double size unit is available: Figure 13 shows both sizes. These elements are plugged into polarized receptacles mounted in drawers, the fronts of which are used to mount lights, potentiometers, switches, etc. The grooves on each element's cover are to guide a probe to test points built into the special receptacle. The receptacle is bottom wired by means of stab-on connectors and flat,

multiconductor, color coded ribbon cables, and is protected by a removable cover. To facilitate modifications and trouble shooting the drawers may be pulled out, inverted, and inserted in a dummy track at the top of the drawer opening without disconnecting the cable. The Directo-Matic panels have vertical and horizontal wiring troughs with removable terminal boards for drawer connections. In this way all wiring is accessible for tracing.

Besides the basic logic elements a number of other analog and digital units are available. Time delay is provided by an element containing two separate circuits of the type shown in Figure 7. This is not a precision timing device, and the nominal delay of 0.1 sec may vary by 50 percent between units; however, repeatability is considerably better. Delay times between 0.05 and 0.1 sec can be obtained by addition of an external rheostat; longer delay times by adding an external timing capacitor.

Other devices that are available include both temporary and permanent storage shift registers and special purpose elements such as a multiplexer having eight inputs and four outputs, a binary counter that will operate up to 25 kc nominal, a one-half decade counter that can be used with the above element to count in binary decimal code, and various ac and dc amplifiers, servoamplifiers, and power supplies.

The low power output of the logic elements can be amplified by a large variety of static and relay elements. For driving indicating lamps there is a low power transistor amplifier available in modules containing either four or eight amplifier circuits. Each input is one load and each output is rated 18 volts at 40 milliamps. Operation of low powered output relays is by similar amplifiers with a load rating of 18 volts at 0.15 amps. Each such amplifier requires an input equal to four loads. The relays used with these amplifiers are usually packaged two to a double sized element, and are high reliability hermetically sealed units with contact ratings to 2 amps at 240 vac and 0.1 amps at 250 vdc. These active elements are used to connect into active element systems or where the added reliability of static amplifiers is not required.

For applications requiring the utmost in reliability, GE uses either higher powered transistor amplifiers or static magnetic amplifiers for the medium power range. High power outputs are provided by large magnetic amplifiers or silicon controlled rectifiers (Ref.6). The latter is a relatively new semiconductor device that has characteristics similar to a thyratron and can be used as a continuous amplifier or in switching circuits.

Westinghouse Electric Corp.

Westinghouse was one of the first companies to apply transistor logic to industrial control. They introduced a line of equipment based on the transistor NOR element in 1956 and have since installed many systems in the steel, process control, and machine tool positioning fields. The system is named PRODAC (Programmed Digital Automatic Control).

The basic NOR element used by Westinghouse is uniquely constructed. As shown in Figure 14, the transistor and resistors are encapsulated and mounted on a printed board containing the desired interconnecting circuitry. A typical printed circuit board including a selection matrix and 14 NOR's is 5 x 8 in. About 1 in. spacing is required between boards giving a packing density of about 2 cu in. per NOR. Other specialized circuit boards could have considerably less volume per NOR.

Westinghouse uses the basic NOR element to construct nearly all special circuits. The NOR elements are grouped on printed circuit cards with the proper interconnections and additional components to form flip-flops, shift registers, counters, etc. This leads to a minimum number of different packaged logic elements, simplifying inventories and making possible volume production of a few elements at a low unit cost.

To amplify the low level signals from their NOR logic, Westinghouse has developed a static ac switch using the silicon trinistor triode (Refs. 7, 8). The trinistor (like GE's controlled rectifier) is a PNPN semiconductor device with characteristics similar to a thyratron that can be triggered by low voltage, low power signals such as provided by transistors. The trinistor ac switch shown in Figure 15 has successfully switched a size 3 contactor and a size 2 contactor connected in parallel. The 2 kva inrush power required in this application was controlled with an input of less than 1 milliwatt, making the switch

FIG. 14. Individual Westinghouse NOR element before mounting on printed circuit board.

FIG. 15. Trinistor ac static power switch by Westinghouse has fast response.

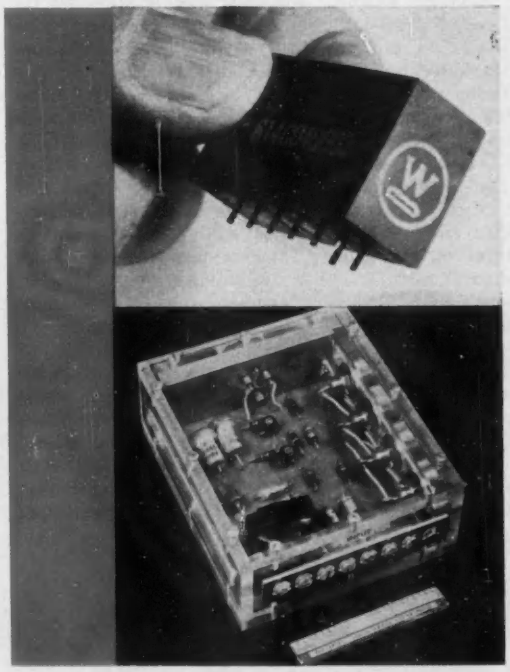


FIG. 16. Clark Controller logic elements use silicon semiconductors for reliability at high temperatures.

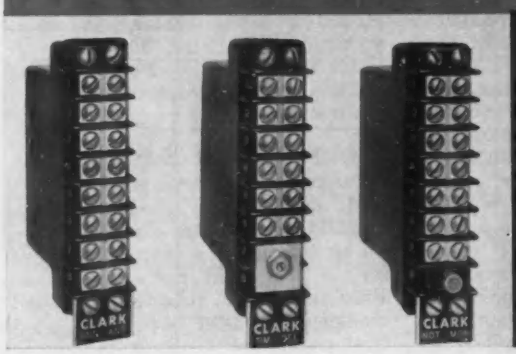
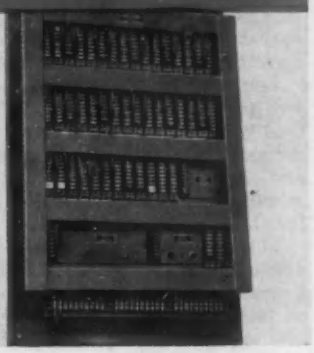


FIG. 17. Typical control panel using Clark Controller's logic modules.



directly usable from transistor logic elements. The switch works equally well under a variety of resistive, capacitive, and inductive loads. Satisfactory operation has been achieved over an ambient temperature range of 0 to 65 deg C, and with line variations of plus or minus 10 percent. Response time is less than one-half cycle of line frequency, six to 12 times faster than an equivalent magnetic amplifier.

Clark Controller Co.

Clark Controller—a newcomer to the field in late 1960—designed its line of transistor switching elements for maximum possible reliability. Their lateness is partially due to the last minute redesign of their logic to use all silicon semiconductors. Experience showed that germanium transistor logic would not meet the high temperature requirements of some applications. Although silicon transistors cost about twice as much as germanium units, Clark believes that this additional cost will be repaid in higher reliability and reduced maintenance. Also, since the logic elements are not the major items in a complete control system, they expect to be competitive on a first cost basis with other transistor systems. This is not true of the individual elements, however, since they cost somewhat more than comparable germanium transistor units.

The logic modules reflect Clark Controller's desire for system simplicity as well as high reliability. Basic elements are silicon diode AND and OR gates supplemented by NOR circuits for amplification. But the NOR is not referred to as such; instead it is called an OR-NOT unit. This stems from the philosophy that service personnel can grasp the concept of the English logic functions much more readily than NOR logic. It is believed that this approach should enable maintenance men familiar with relay circuits to trouble shoot transistor systems with practically no special training.

The basic logic elements are housed in butyrate cases and potted in epoxy resin. Screw terminals are used as a positive and proven method of electrical connection, without the need for special tools or parts. Wide terminal spacing also makes the elements less susceptible to the effects of contaminant buildup from dirty atmospheres. The element package is about 1½ in. wide, 4⅜ in. high, and 3½ in. deep, and can house one to four circuits depending on their complexity. The left-hand element in Figure 16 contains two three-input AND circuits. The center element is a time delay unit, variable from a fraction of a second to several seconds by the screwdriver adjustment on the front. Longer delays can be obtained with an external capacitor. This timer circuit is different from others presently available in that its reset time is less than 1 millisec. It uses a silicon unijunction transistor, a relatively new device.

The element on the right is a combination NOT (inverter) and monitor light unit. Normally the incandescent monitor lamp is included on the unit (just above the nameplate in the photo); however, it can be mounted remotely if desired. The element contains the necessary amplification to drive the lamp from logic inputs and can therefore be used for operational sequence indication as well as trouble shooting. For the latter purpose it is recommended that several extra units be included in the panel.

In addition to the above devices, flip-flops, components to form shift registers, amplifiers, and permanent and off-return memories are available. Speed of all logic elements is at least 25,000 operations per sec. Design temperature is 40 deg C ambient; however, all units will operate well above this figure. The special channels and wiring ducts shown in Figure 17 are used to produce a rugged and accessible panel layout.

Original inputs can be from push buttons, relays, limit switches, or other conventional devices. For short runs 105 vdc is used on contact-making devices and then attenuated by a six-input signal converter on the control panel to provide the proper inputs to the logic. For long runs where noise pickup may be a problem 115 vac is used and is stepped down, rectified, and filtered by a converter.

Output amplifiers include a 6-watt at 12-volt transistor amplifier for low power output devices. In the 100 to 150 volt-amp range there are two amplifiers using controlled rectifiers: one provides an ac output, the other dc. Planned, but not yet available at the time of writing, is a larger controlled rectifier amplifier in the 500

to 1,000 volt-amp range. All output amplifiers operate from power supplies separate from the logic elements to prevent interaction.

Logic element power supplies include one that will power approximately 50 units and another that will handle 100 or more. These supplies incorporate saturating transformers for regulation and are protected from line transients by selenium suppressors. A separate supply is used for the 105-volt signal inputs.

The ways transistor logic fails make it more difficult to design an absolutely fail-safe system. Transistors usually produce a shorted condition on failure; however, they can also fail open. To get around this situation Clark Controller is working on a line of special high speed magnetic logic units that will be compatible with their transistor logic and about the same size. Their advantage will be that failure modes can be predicted better, making it easier to attain maximum reliability. The magnetic logic elements will be capable of at least 1,000 operations per sec, which is fast enough for most control applications.

Computer-Type Logic Modules

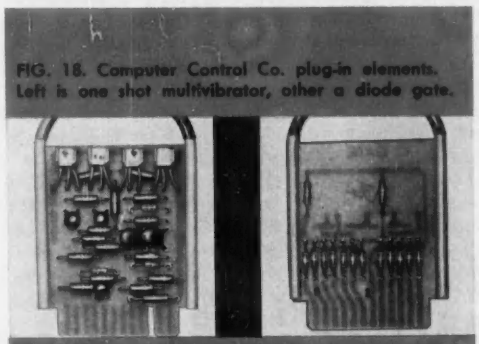


FIG. 18. Computer Control Co. plug-in elements. Left is one shot multivibrator, other a diode gate.

FIG. 19. Digital Equipment Corp. logic element has rugged connector for reliability.

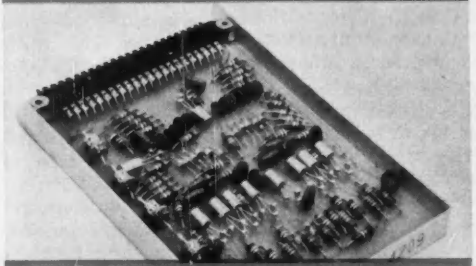
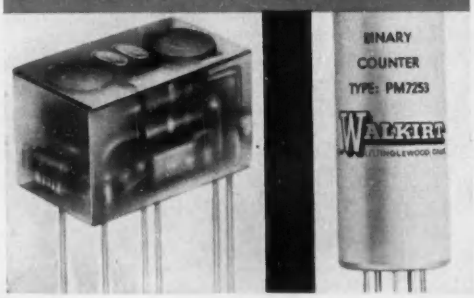


FIG. 20. Completely potted and encased computer-type elements by The Walkirt Co.



Computer-type elements

Packaged transistor logic circuits were first made available for use in breadboarding and in building computer circuits. The great interest in this field in the last few years accounts for the large number of elements currently available. In general, these elements are capable of considerably faster operation than their industrial counterparts. Even though they are not packaged for industrial service, they have found many applications in such areas as steel mill control, milling machine control, and other special situations: some are discussed later in the article. Computer-type elements are well suited for complicated digital control systems requiring a high information rate. They are available primarily as components, although some manufacturers will also do the systems engineering if requested. It is interesting to note that many of these complicated control systems are actually small, special purpose digital computers, though they are not usually thought of as such.

Many computer-type elements now on the market are built on printed circuit cards, such as shown in Figure 18. These retain the advantages of quick substitution and the possibility of individual component replacement. Some have connectors on the printed circuit board, Figure 19, which improves reliability in adverse atmospheres. Computer-type elements can be used for many factory floor applications if they are housed in heavy duty cabinets capable of protecting them from dust and dirt and from mechanical damage. Moisture and corrosive atmospheres are still a problem, but sufficient protection can usually be obtained by dip coating the cards with a conformal plastic coating. Figure 20 shows one of several available lines that are protected by cases or complete potting.

The basic elements available are typified by those discussed under computer-type circuits in the preceding section, although the actual circuitry is usually more complicated. Table 1 is a partial listing of typical computer-type elements and their important characteristics. Most of the lines are similar insofar as available circuitry is concerned, and nearly all are amenable to industrial use. .

There are two basic types of logic systems: leading edge and pulse. All the examples cited in the application section of this article use leading edge logic. Here the signal is conveyed by a change in dc level, the level being maintained as long as the signal is present. Pulse logic uses a dc level to gate a standard pulse, usually derived from a clock source. For control applications the leading edge type of logic is usually easier to apply because it tends to simplify the required circuitry by eliminating excessive nonlogical gating.

Table 1 SOME OF THE COMPUTER-TYPE ELEMENTS YOU CAN BUY

Manufacturer	Temperature range, deg C	Size, in.	Speed	Supply voltages required	Signal level, volts	Logic type — leading edge or pulse	Construction	Circuits Available: Flip-flop	One shot m.v.	Diode gates	Inverter	Neon lamp driver	Emitter follower	Pulse or buffer amplifier	Blocking oscillator	Shift register	Counter or binary	Oscillator	Nixie driver	Schmitt trigger	Power amplifier	NOR	Transistor gate
AVCO CORP. (Note 1)		2¾ x 1¾ x ⅝	dc – 1 mc	+15, +1.5 —10, —12.5 —15, —25	0 —10	LE	Printed ckt in frame with connector	✓	✓	✓	✓	✓	✓										
COMPTRON CORP.	0 55	6 x 3 13/16	15 – 500 kc	+45, +12 —1.5, —3, —45	0 +12	P	Printed ckt card	✓		✓	✓			✓		✓	✓	✓			✓		
COMPUTER CONTROL CO.	— 20 + 55	4 x 2⅞	dc – 100 kc (Note 2)	+20, —90	0 +10 min.	LE	Printed ckt card with handle	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
DIGITAL EQUIPMENT CORP. (Note 3)			500 kc 5 mc 10 mc	+10, —15	0 — 3	P	Printed ckt card in frame with connector	✓	✓	✓	✓			✓		✓	✓	✓		✓	✓		✓
ENGINEERED ELECTRONICS CO. T-series	— 45 + 65	2 1/16 x ⅞ diam	dc – 250 kc minimum	+12, —12	— 3 —11	P & LE	Sealed container with min. tube-type pins	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	
ENGINEERED ELECTRONICS CO. W-series (silicon)	— 45 +100	2⅞ x 2 1/16	dc – 150 kc @ 100 deg C	+20, —20	+ 6 +16	LE	Printed ckt board	✓	✓	✓		✓	✓		✓								
EPSCO INC.	— 55 + 71	2 x 0.9 x 0.9	dc – 200 kc	+18, +6, —6	0 — 6	LE	Potted with tube-type pins	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
KELLOGG SWITCHBOARD & SUPPLY CO.	— 50 + 70	2½ x 2	dc – 100 kc	+12, —12	0 —12	LE	Printed ckt mounting on special printed ckt board	✓		✓			✓	✓									✓
NAVIGATION COMPUTER CORP. 300 series (Note 4)		5 x 6	dc – 300 kc	—12		P	Printed ckt card	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓		✓	✓	
PLUG-IN INSTRUMENTS INC.	0 50	2⅞ x 5¼ x ½	dc – 150 kc	+12, —12	0 —10	LE	Printed ckt card with frame and connector	✓	✓	✓		✓	✓	✓									
RANSOM RESEARCH		4½ x 5	To 500 kc (50 kc – NOR)		0 + 8	P & LE	Printed ckt card	✓		✓			✓				✓					✓	
WALKIRT CO.	— 20 + 85	2 1/16 x ⅞ diam	Depends on circuit; dc – 100 kc minimum	—6, +6, —18	6 nominal	LE	Epoxy potted with min. tube-type pins	✓	✓	✓	✓		✓				✓	✓	✓	✓			
VITRO LABORATORIES		3½ x 1⅜ diam	dc – 250 kc and higher	—6, +6, —⅕		LE	Cased with 12-pin base	✓	✓	✓		✓		✓						✓	✓		

NOTES

1. The logic elements manufactured by AVCO use a new PNPN switching device instead of conventional transistors.
2. Computer Control Co. also has a 1 mc line of logic elements.
3. DEC has two lines of elements available. One, "Digital Test Equipment," is designed for breadboard use and has all terminals brought out to a diagrammed front panel. The "System Building Block" packages are conventional printed circuit plug-in's.
4. Also makes a modular packaged line of logic elements.

TIPS ON SELECTION AND USE

When static magnetic systems were first brought out several years ago, attention was focused on the problems associated with reliable input and output devices. At that time it was feared that mechanical push buttons and limit switches would be weak links in an otherwise very reliable system. In most cases these fears have failed to materialize. The use of dc signals in the 130-volt range on mechanical input devices has eliminated the problems of oxidation and contact resistance in low voltage circuits. This signal is attenuated by a simple resistive voltage divider to provide the proper input voltage. For long runs where electrical noise may be a problem, ac signals are used and then conditioned for input to the logic elements.

Limit switches, particularly of the proximity type, have been improved (Ref. 9). New proximity switches are available using all solid state components that will provide the proper voltage levels for transistor logic inputs. But their cost will never be comparable to mechanical switches, so that increased reliability through the use of proximity switches will cost more.

Output devices are also less of a problem than they used to be. Reliable transistor amplifiers are available for the low to medium power range, handling loads such as clutches and solenoids that may operate on a high duty cycle. Medium and high powers can be handled by other semiconductor devices such as silicon controlled rectifiers or by magnetic amplifiers. However, these devices will not replace heavy contactors and motor starters which are sufficiently reliable for nearly all applications. Reliability will cost the most in the area of output amplifiers; however, if relay devices are satisfactory, special reasonably-priced ones are available for use with transistor logic.

Nearly all semiconductor devices are very sensitive to overloading and can be burned out in a fraction of a second by exceeding their voltage or power rating. Such overloads can be caused by large line transients, improper connection, or shorting of terminals. The first of these is usually prevented in the power supply by the use of a saturating transformer or semiconductor voltage regulator circuit, or, where excessive line transients are expected, by selenium surge suppressors. Many circuits are self-protecting against improper connection. This is true of even the more complicated computer-type circuits if only one type of transistor is used (PNP or NPN), and emitter followers are eliminated. In most cases there is sufficient resistance in series with the input or output to limit current flow to less than destructive values in the event of improper connection. To minimize the possibility of any connection between power lines and the logic system, all low voltage transistor circuitry should be separated from power equipment.

The selection of logic elements necessarily depends on the application. NOR logic can be used to implement any logic system within its speed range. It is particularly well suited to the direct replacement of relays because of the simplicity afforded by a single logic element approach. Small systems also benefit from this approach since only one type of spare element must be provided and modifications do not require a substitution of logic elements. But NOR logic is not limited to small systems, and any system using mostly AND, OR, and NOT functions is a natural choice for NOR logic. If there are many timing functions, storage requirements, shift registers, etc., however, it may pay to construct the system with a line having the desired elements instead of synthesizing them from NOR's. This often ends up as a matter of personal choice, although speed, packaging, and cost will also be considerations.

What are the cost factors?

The cost comparison between transistor logic and relays varies depending on the particular control system. The three most influential factors are the cost of the logic elements, output amplifiers, and power supplies. Logic elements, particularly the less expensive industrial NOR's, are competitively priced with relays at under $10 each. The faster computer-type elements are more expensive per element, but not usually so on the basis of operations per unit time. Since the speed of these units is at least 100,000 operations per sec, they are in a different class than relays and any price comparison is absurd.

At present both transistor and magnetic output power amplifiers are being used with transistor logic, although the trend appears to favor transistor units for medium power outputs up to approximately 100 watts. In this range transistor amplifiers are somewhat less expensive than magnetic amplifiers of the same power rating: a 30-watt transistor power amplifier is now available from one manufacturer for $30. Controlled rectifiers will also be used for ac and dc outputs of 100 volt-amp upwards as their steadily decreasing cost makes them more competitive.

Power supplies are generally designed to provide power for about 100 logic elements. If they are used to their full capacity the cost per element is small. But for small systems with fewer than 40 or 50 logic elements, power supply cost may be a significant portion of total cost.

At present transistor logic costs about the same as magnetic logic, but the case for transistor logic should get brighter in the future. Magnetic amplifier production techniques and technology are well developed and there is little hope for significant price reduction. The same is certainly not true of semiconductor devices, however. Prices have been steadily decreasing and new and improved devices are being introduced. If present trends continue, transistors

and other semiconductor devices should be competitive for the majority of control applications in the near future. This is on the basis of first cost. At present if it is possible to design a control system with relays, its first cost will probably be less, but when reliability, down time, and maintenance are taken into account the long term cost picture may be decidedly different.

Problems of fail-safe systems

The problems of designing a transistor logic system to fail safe are not too different from those of relay systems, except that gravity is no longer a factor. Transistor NOR logic in particular fails in a manner similar to relays: if the transistor opens the circuit delivers an output signal under all conditions, if it shorts out there is no output. The latter is most likely to occur. Computer-type logic usually fails in a similar manner, either producing a continuous output or none.

Where several different inputs must all be present for a given result to occur, the same general technique used on punch press controls is applicable. Here not only must the required signal be present, but it must have been turned on since the previous cycle. This insures that the input device has not failed or been locked on. Similar checks can be incorporated anywhere in a control system to monitor its operation and take appropriate action should a malfunction occur in any element up to that point. Where such checks are provided at least two elements in different circuits must fail simultaneously for an improper output to be possible. If the failures are not simultaneous, the condition is detected before an improper output results. The high reliability of transistor logic makes such an event statistically improbable.

Another possibility is to use the parity check technique, commonly employed in digital computer circuits (Ref. 10). This provides for recognition of certain permissible signal patterns and delivers an output if it detects an improper combination. In applications such as program control, such a circuit can detect either improper input data or malfunction of any circuitry up to that point. In the extreme case, error correcting circuitry can be incorporated.

Creating the switching system

System design using transistor logic elements is basically no more difficult than the design of relay systems. This is particularly true if the control engineer has used either Boolean algebra or English logic functions for relay switching systems. Once a logic diagram has been obtained, the substitution of the actual transistor elements is simple, since each one is a compatible logic function. For the user of packaged logic this eliminates all but elementary considerations of the actual element circuit.

There are three general approaches to transistor logic circuit designs. If a relay system is already available, or required for the purpose of cost comparison, it can be translated directly into an English logic diagram. Each logic block is then realized with the corresponding transistor logic element (or its functional equivalent if NOR logic is used). The resultant circuit is then simplified to remove unnecessary or duplicate functions. This can usually be done by inspection although the ultimate in simplification may not result.

A second approach, which will usually be more convenient once the designer is familiar with available logic elements, is to draw a logic diagram directly from the required functions. Substitution and simplification can then proceed.

If the system is large and complicated it may be best to take a more formal approach. In this case the Boolean algebra expressions are written for each section of the system, and simplified and combined mathematically as the design progresses. Many procedures are available for simplifying the mathematical expressions to get a minimal system (Refs. 11, 12). These can be applied to Boolean expressions directly or, in some cases, can be used to derive simplification procedures for use at the logic diagram level without resorting to Boolean expressions. Once the complete algebraic equations are derived, substitution of logic functions follows a straightforward procedure.

About the only difference in design between systems using industrial-type elements and those using computer-type elements is in the logic functions that are available. When using systems based on NOR logic, it may be necessary to substitute several elements to get a given logic function. Many of these will later be removed during simplification. Computer-type logic has additional elements and, as previously shown, these may or may not include inversions. Output capabilities also differ between units so that in some cases buffer amplifiers must be added to prevent excessive loading.

System design can proceed in the same fashion regardless of the elements used. Work backward from the required outputs towards the inputs, filling in the necessary logic for each output from the various input conditions that determine it. Tabulations of the inputs, truth tables, etc., will be of advantage here. One trick that is often applicable to circuit simplification is the use of inverse inputs. Determine the conditions under which an output is not desired and implement them using one final inversion. Also, if the input from a push button, switch, etc. must be inverted to provide the proper logic input, it may be possible to use the normally-closed contacts instead of the normally-open to save the logic element that would have been necessary for inversion.

System modification, once it has been completed, is usually fairly easy. This is particularly true for those systems that use solderless connections: relocated connections often do the trick. It is good practice to allow a few spare elements, or room for them, in the original layout to facilitate such last minute changes.

SIX CASE STUDIES SHOW TRANSISTOR LOGIC AT WORK

In the last four years the rate of application of industrial transistor switching has gone up with the increase in experience, confidence, and number of supply sources. The following case studies are indicative of the directions in which it has gone: three are in the steel industry, and one each in machine tools, pipelines, and sport-ball winding. The spread is typical; besides the major concentration in steel you are likely to find transistorized logic used on any process or machine where reliability, size, speed, weight, or sheer complexity of switching are critical.

1. Pumping station annunciator control

Size was a key factor in Cooper-Bessemer's specification of this Norpak annunciator control by Square D. The system monitors the operation of a 2,500-hp V-angle compressor on a natural gas pipeline running from Texas to the Northeastern states. The large two-cycle engine driven compressor units, Figure 21, use the gas being pumped for fuel, permitting completely automatic operation of the stations.

Safety requirements dictate that all electrical controls be mounted in expensive explosion proof housings. Here the small size of the Norpak units became a factor since the money saved through the use of a smaller housing helped to offset the higher initial cost of transistor logic. Reliability was obtained at a reasonable price.

The annunciator control monitors two groups of points, Figure 22. One group indicates abnormal operation requiring an operator's attention, the other notes major failure points that will cause the whole system to shut down. If an alarm point goes off normal, local and remote lights identify the variable, and local and remote audible alarms sound. If a shutdown point goes off normal, the results are similar except that the compressor shuts down.

Any number of alarm point indicators can be energized at one time, whereas only one shutdown indicator can be energized at a time. After each alarm point indication the audible alarm can be silenced, however the alarm will sound again if another point goes off normal. All alarm points automatically reset themselves on return to normal. But after a shutdown point goes off normal, the system must be manually reset. The reset will only remain valid if the point in question has returned to normal.

The English logic diagram of a typical shutdown point monitoring channel is shown in Figure 23A. This channel has a permanent memory so that it remembers being tripped even if power fails after tripping. The light output comes on as the normally-closed monitoring contacts are opened, and stays on until the fault is cleared and the reset button pressed. The audible alarm output also turns on as soon as the contacts open, but can be silenced by pushing the reset button. The third output provides the shutdown signal and locks out all other shutdown points.

With the contact closed and the circuit reset, NOT element *a* has an input and no output, and retentive memory *d* is reset giving no output. None of the outputs is energized. When the contact opens, there is an input to AND gate *c* from both *a* and *b*, setting the retentive memory and providing the shutdown signal and light indication. Memory *g* is reset so that NOT *h* in conjunction with the output of *d* energizes AND gate *i* sounding the alarm. Pressing the reset button sets memory *g* via AND gate *f*, silencing the alarm. In addition, if the fault has been cleared, both inputs to AND gate *l* will be present, resetting both memories and turning off the lights and shutdown and lockout signal.

The typical alarm point channel in Figure 23B has no permanent memory and resets itself as soon as the fault is cleared. When the contact opens both outputs come on; however, the alarm can be silenced by pressing the reset button. In the reset condition memory *o* is off providing no output to NOT *p* which in turn delivers an input to AND gate *q*. This in conjunction with the output of *m* on loss of input sounds the alarm. The light is energized directly from the inverted input. The reset pulse in conjunction with the output of *m* sets memory *o*, silencing the alarm. When the input returns to normal, the light automatically clears.

The circuits are shown in NOR logic notation in Figure 23C, below the corresponding English logic diagrams. The off-return memories are constructed of two NOR elements. This shows that NOR elements can replace all English logic units without an increase in circuit complexity. Figure 24 shows the actual Norpak annunciator.

2. Data accumulation for a coil preparation line

The Westinghouse PRODAC system of Figure 25 accumulates data from a sheet material coil preparation line. It uses NOR logic throughout; the plug-in packages are shown in the left-hand side of the control panel. One of the purposes of the coil line is to inspect the sheet for pinholes and off-gage defects automatically. The presence of one or more defects in any part of a linear foot rejects the whole, while a foot of material containing no defects is a prime foot. Since the line runs at a speed of several thousand feet per minute, information must be presented to the operator quickly and accurately. This is accomplished both visually and in permanent printed form. The information consists of the totals of prime and defect footage and a calculated value of percent prime.

System operation is shown in Figure 26. A

TRANSISTOR LOGIC MONITORS ENGINE-COMPRESSOR VARIABLES

FIG. 22. Off normal condition in upper variables shuts down compressor, in lower variables it simply sets the alarm.

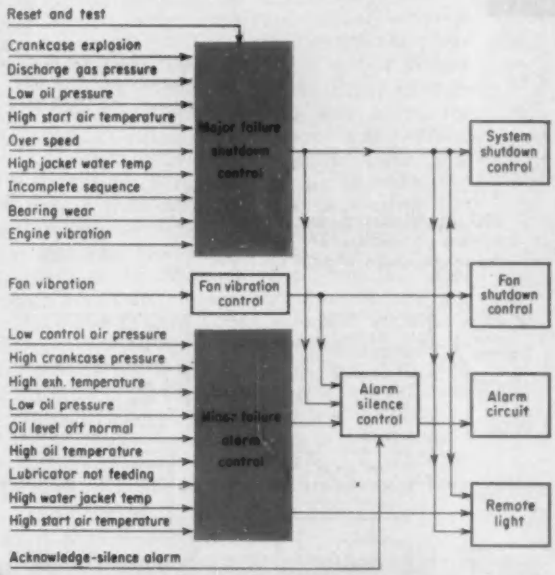
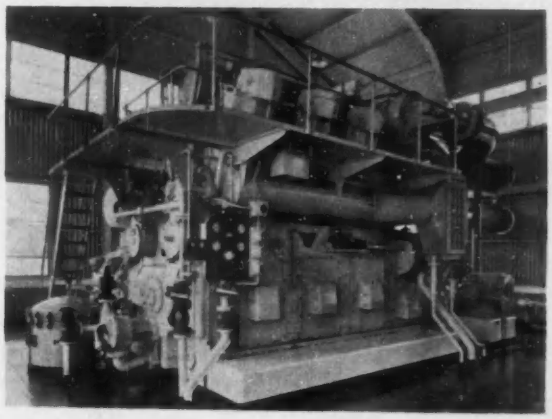


FIG. 21. Annunciator checks on engine driven compressor supplied by Cooper-Bessemer for natural gas pipeline.



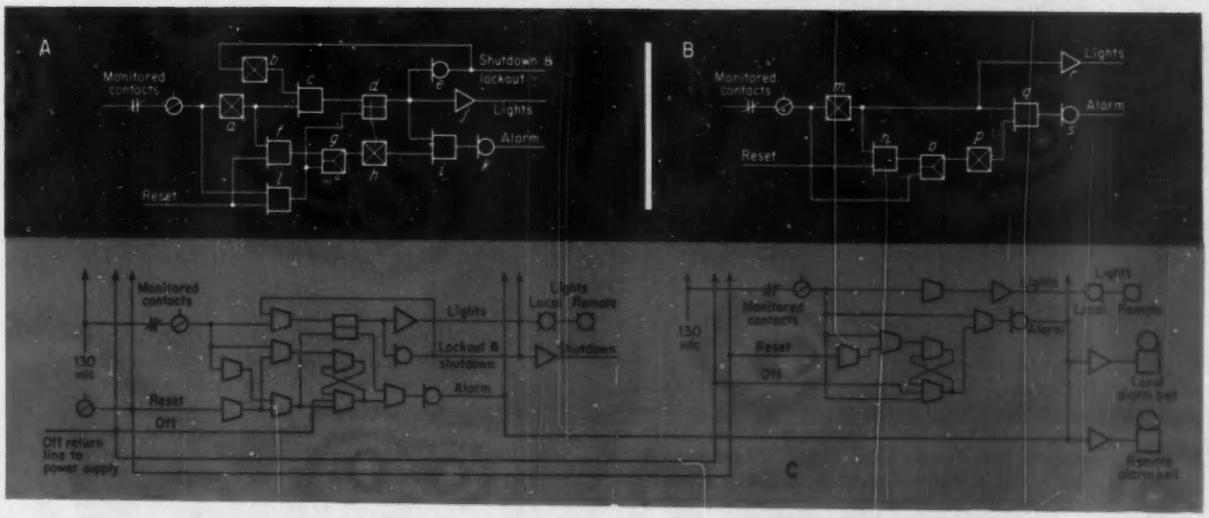
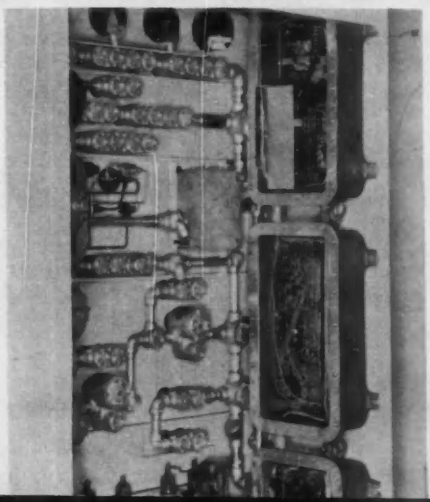


FIG. 23. English logic diagrams of shutdown point and alarm point monitoring circuits in A and B. C shows equivalent circuits in NOR logic notation.

FIG. 24. Small size of Norpak units adapts well to explosion proof housings.



DATA ACCUMULATOR KEEPS TRACK OF SHEET DEFECTS

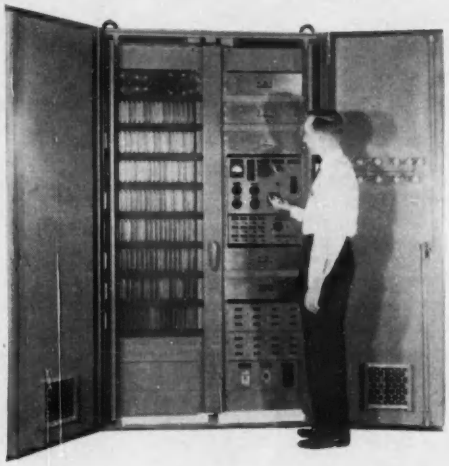
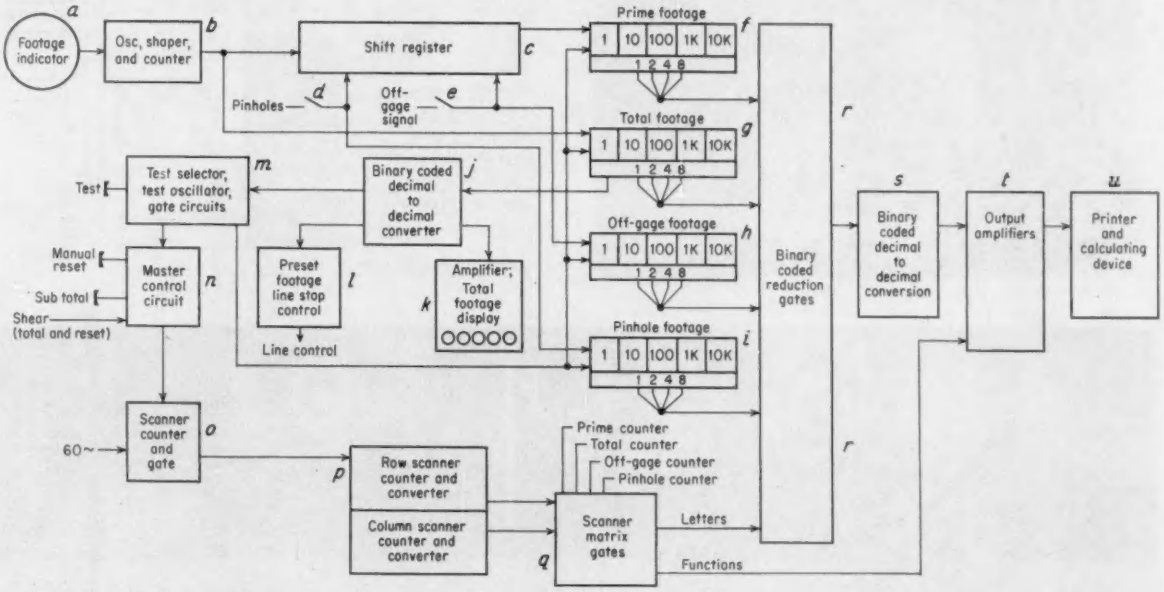


FIG. 25. Westinghouse PRODAC control panel for data accumulator has NOR packages on left-hand side.

FIG. 26. All special logic functions in data accumulator are performed by combinations of NOR's.



footage indicator *a* signals an oscillator, shaper, and counter *b* which puts out a single pulse for each foot regardless of speed. These pulses represent total footage and are therefore counted by binary coded decimal counter *g*. All counters are constructed from NOR logic elements. Total footage is a desired output so that counter contents is fed to conversion matrix *j* where it is converted to a decimal number and displayed.

Defects are detected by two different instruments. A signal from pinhole detector *d* feeds pinhole counter *i*. The first defect in any foot triggers the counter which is then blocked by a gate for the rest of the foot. At the end of this foot the next foot pulse resets the gate to accept the next pinhole. This insures that only one pulse for every defect foot will be counted regardless of the number of pinholes present. The off-gage indicator functions similarly.

Because of their size and construction, the two defect detecting instruments must be placed serveral feet apart. This necessitates some means of correlating the location of pinholes and off-gage defects, accomplished by shift register *c* in this case. NOR elements are connected to form a shift register with the same number of stages as the distance in feet between the detectors. Foot signals are fed into the register and shifted along each time the footage counter determines that a foot of material has passed. If a given foot has a pinhole the signal corresponding to that foot will be removed as it passes the stage corresponding to the location of the pinhole detector. The absence of a signal then continues to be shifted down the register for that particular foot. The off-gage detector functions similarly, except that if there is a pinhole in the same foot that is off gage, the signal corresponding to that foot will have already been removed when it reaches the off-gage detector position. Only prime footage signals are counted by *f*.

As an operator aid, preset limit *l* slows down or stops the line when a given count is reached. Control of all accumulation sequences is from master control *n* which provides for either manual or automatic operation.

To obtain a printed record from all counters, each of the four binaries in each decade of each counter is scanned at a rate determined by pulse generator *o*. This unit divides down the 60-cps line frequency to provide the desired output pulse rate. This scanning pulse causes a "row and column" matrix to advance point by point, selecting each row and column intersection for a definite length of time. The scanning program includes reading the counters, and reading out certain prewired letters and instructions.

Binary coded reduction gate *r* reduces the multiplicity of inputs of stored and programmed information into four lines giving a binary coded decimal output. This is converted to a decimal signal in *s*, amplified, and used to actuate a mechanical calculator/printer *u*, which makes a division to determine percent prime footage and prints out all data on adding machine tape.

3. Milling machine contouring control

A good example of the use of computer-type logic elements in an industrial application is the prototype numerical control system for a 16 x 32 vertical Hydrotel milling machine designed by the Electrical Product Development Dept., Tapco Group of Thompson Ramo Wooldridge. The director is completely transistorized and consists of approximately 500 Computer Control Co. plug-in logic elements, Figure 27. Taking a digital input from punched paper tape the director-interpolator produces phase-shifted analog square wave signals. These are the inputs to the analog servosystems that produce the machine motions.

Each tape block contains a change order for each axis, a clock cycle code that determines the time interval over which these changes must take place, and auxiliary control data. As shown in Figure 28, information is read from the tape, through a data distributor, and into intermediate storage. The change order data for each axis consists of a five digit binary coded decimal number representing the distance to be moved plus one bit for sign. These orders plus a speed code are stored in a bank of flip-flops, which comprise the intermediate storage, and are held there until transferred to final storage when the machine completes the previous operation. Transfer time

COMPUTER-TYPE ELEMENTS MAKE UP NUMERICAL MACHINE DIRECTOR

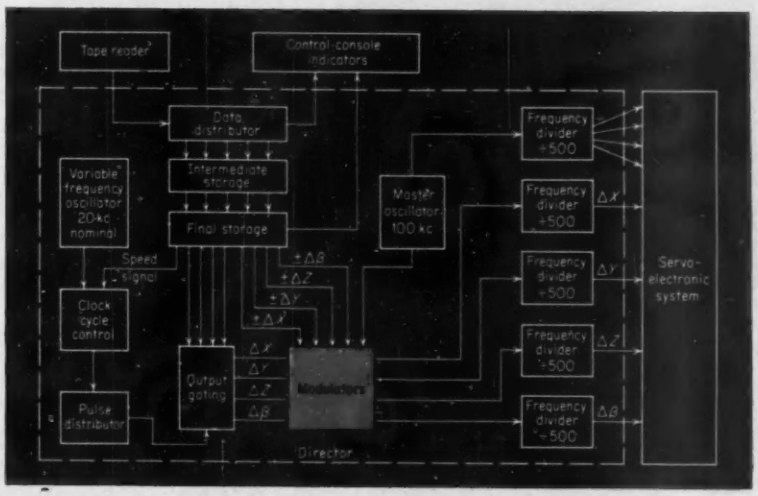
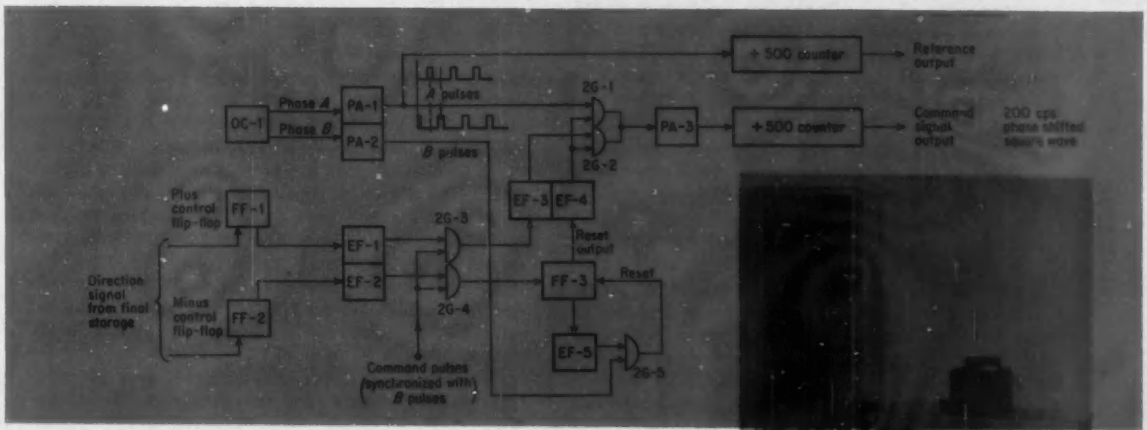


FIG. 28. Simplified data flow diagram for TRW director.

FIG. 29. Detailed logic for modulator shown in Figure 28.



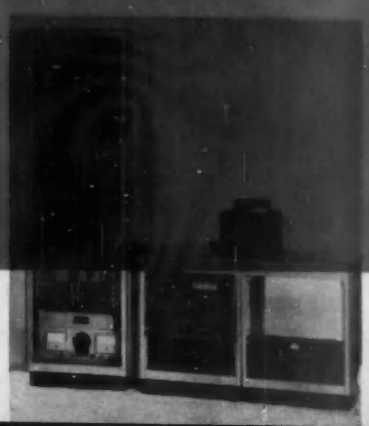


FIG. 27. Thompson Ramo Wooldridge director.

is so short that machine operation is continuous even though the tape is read intermittently.

The speed at which the machine carries out the command is determined by the clock cycle control. It consists of a binary counter chain which divides the output from the variable oscillator. Submultiples of this oscillator frequency are selected by gating the output from the proper counter stage as selected by the clock counter code in final storage. This provides a pulse train, the repetition rate of which is proportional to the desired speed.

Operation of the pulse distributor is similar to that of the clock cycle control. It contains a counter chain, the noncarry outputs of which are gated to four output lines, one for each machine axis. A counter of this sort has the property that every pulse fed in appears either at one of the noncarry outputs or at the end-carry output. Since these pulses never coincide in time, the counter may be used as a variable divider by controlling the gates to provide the desired division ratio. It is in this fashion that the change order in final storage is used to gate out the required number of pulses from the output of the clock cycle control. Each pulse train from the output gating circuit contains a number of pulses proportional to the distance that particular axis is to move. The velocity of each axis is determined by the pulse rate and remains constant for each block of information.

The command pulse train representing the change order for each axis is fed to a modulator along with sign information from storage which determines the desired direction of motion. If the sign is positive, the pulse train is added to a 100 kc master oscillator signal; if it is negative, it is subtracted. Each modulator output is divided by 500 to produce a 200 cps phase modulated square wave. The 100 kc master oscillator output is also divided by 500, producing a reference 200 cps square wave. The outputs actuate electrohydraulic machine drive servos using resolvers as feedback elements.

To illustrate the use of computer-type logic elements, the modulator section of the director for one axis is considered in more detail, Figure 29. The 100 kc master oscillator *OC*-1 puts out two separate output signals 180 deg out of phase. These are shaped by pulse amplifiers *PA*-1 and *PA*-2 to produce *A* and *B* pulse trains, each at 100 kc but with the *B* pulses evenly spaced in time between the *A* pulses. The A pulses are divided by 500 to produce the reference output.

Performance of the rest of the circuit depends on whether the change order in final storage is positive or negative. If negative, minus control flip-flop *FF*-2 is set. Its output enables AND gate 2*G*-4 after being buffered by emitter follower *EF*-2 to prevent loading effects. Enabling this gate permits passage of the command pulses which have been synchronized to occur at the same time as the *B* pulses. When a command pulse passes through gate 2*G*-4 it sets flip-flop *FF*-3 and removes the reset output to emitter follower *EF*-4, disabling AND gate 2*G*-1 and preventing passage of *A* pulses to the output divider. Simultaneously the output of flip-flop *FF*-3 enables gate 2*G*-5 through emitter follower *EF*-5. This permits the next *B* pulse to reset flip-flop *FF*-3 and again allow passage of *A* pulses to the output divider.

Since the command pulse that initiated the above sequence occurred at the same time as a *B* pulse, the *B* pulse required to reset the system could not occur until after one *A* pulse had been lost due to the disabling of AND gate 2*G*-1. In this way, one pulse is subtracted from the *A* pulse train that produces the command signal output for each command pulse. This loss results in lengthening the time necessary to pass 500 pulses into the divide-by-500 counter, thereby lengthening that portion of the square wave. This causes a phase shift.

A positive change order in final storage sets *FF*-1 which in turn enables AND gate 2*G*-3 allowing command pulses to pass. Flip-flop *FF*-3 is normally reset which enables AND gates 2*G*-1 and 2*G*-2, permitting passage of both *A* pulses and command pulses. The outputs of 2*G*-1 and 2*G*-2 form an OR gate which, in effect, adds the two pulse trains, shortening the time for 500 pulses and producing a negative phase shift of the output square wave. If the change order is zero, no command pulses are generated and the command signal output is in phase with the reference output.

4. Rolling mill numerical screwdown control

An interesting application of Norpak logic is the numerically controlled screwdown system developed and built by the Electric Controller and Manufacturing Div. of Square D Co. The system can control the roll spacing for each pass in the mill schedule. As shown in Figure 30 the input in the form of an 11-bit binary number can come from a number of different devices. This input specifying the roll opening in increments of $\frac{1}{32}$ in. to 64 in. is compared with the feedback signal from the mill in a numerical subtractor/comparator to determine how far and in what direction it is necessary to move the rolls.

Synchros feed back screwdown-drive position information to a shaft encoder via a mechanical differential. Since encoder output is in Gray code it must be converted to binary by the Gray to binary converter. The converted feedback signal can then be compared with the input. The output from the subtractor/comparator is a numerical signal representing the distance the rolls must be moved, plus a second signal giving direction. The digital to analog converter changes the numerical signals to a polarity-sensitive analog voltage which signals the motor controller to actuate the screwdown motor.

Roll wear and other variables affecting roll opening can be compensated for semiautomatically by the synchronizing system, shown with broken lines in Figure 30.

Both the Gray to binary converter and the subtractor/comparator are completely static using

NOR LOGIC PERFORMS COMPUTER FUNCTIONS IN ROLL POSITIONER

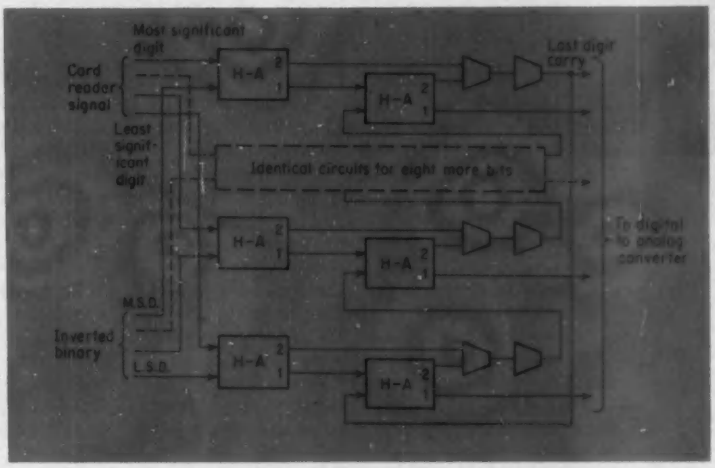


FIG. 32. Eleven-bit binary subtractor/comparator.

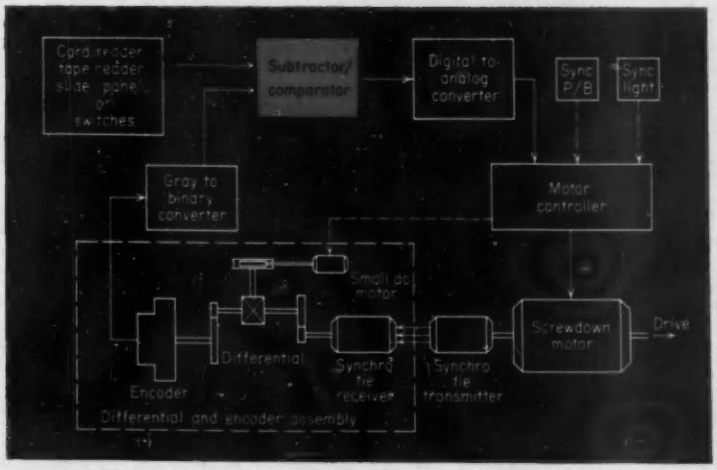


FIG. 30. Numerical input is processed by transistor logic to control successive roll gaps.

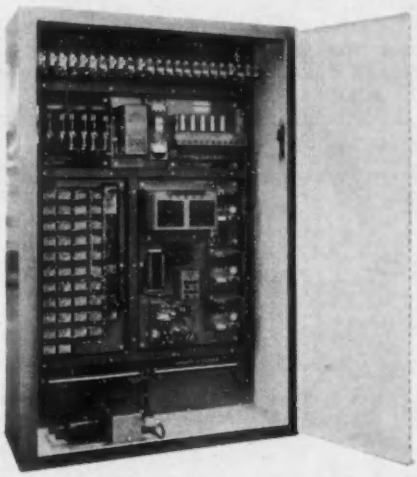


FIG. 33. Screwdown positioner control panel developed by EC&M Div. of Square D using Norpak logic units.

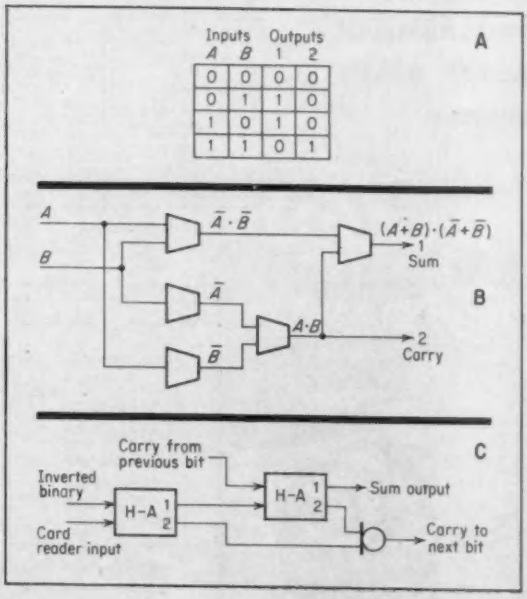


FIG. 31. The truth table for a binary half-adder in A can be implemented by NOR logic as shown in B. Two of the B circuits are necessary to form the binary full-adder in C.

Square D's Norpak units. The two units use several identical logic circuits known as half-adders, and a discussion of the subtractor/comparator is representative of the system logic.

The subtractor/comparator is an example of a common computer operation being performed with industrial-type logic elements. It performs a binary subtraction defined by these rules:

- Invert the subtrahend, add to the minuend.
- If there is a carry from the last digit add one. The answer is positive or zero.
- If there is no carry from the last digit invert. The answer is negative or zero.

Since it is as easy to convert from Gray to inverted binary as from Gray to binary, the former is done, automatically performing the first operation of the subtraction.

The truth table of Figure 31A shows the logic required to add two binary digits. Output 1 is the sum output and output 2 represents a carry. Figure 31B is the corresponding half-adder circuit built with NOR elements. As the name implies, two of these circuits are necessary for each binary digit that appears in the numbers to be added. The first sums the two digits while the second provides for the carry signals. Designating the half-adder circuit as a box, Figure 31C shows their connection to form a full adder.

Eleven of these full adder circuits are combined to form the subtractor/comparator of Figure 32. This circuit operates on one inverted input to give the difference according to the rules given above. Absence of a last digit carry causes the output to be inverted. This operation is accomplished in the digital to analog converter and is therefore not shown on the diagram. The last digit carry signal is also used to indicate the direction in which the rolls must be moved. A 1 signal indicates forward operation while lack of a carry (0) indicates reverse. Figure 33 shows the mill system control cabinet.

5. *Programmed ball winder control*

Computer Control Co.'s electronic program controller for ball winding illustrates a relatively small transistor logic application. The system uses approximately 50 M-Pac logic units and was designed and built for the General Tire and Rubber Co. Originally intended to produce basketballs, it has been adapted to winding all types of round balls.

The purpose of the controller pictured in Figure 34 is to produce an evenly wound ball. This is accomplished by regulating both the number of oscillations of the ball winding control during the wind phase and the time interval during the pause phase. Counter *C*-1 in Figure 35 controls these two functions alternately from two different inputs. One is from a photocell which provides the signal indicating the number of revolutions during the wind phase. The other is from a frequency doubler on the 60 cps line which gives a 120 cps signal for timing the pause.

Each of these two signals is applied to AND gates *G*-1 through individual Schmitt triggers that shape the inputs to provide a clean pulse. These gates are alternately enabled by the outputs to the brake and clutch. During the pause

SIMPLE LOGIC PROGRAMMER WINDS BALLS EVENLY

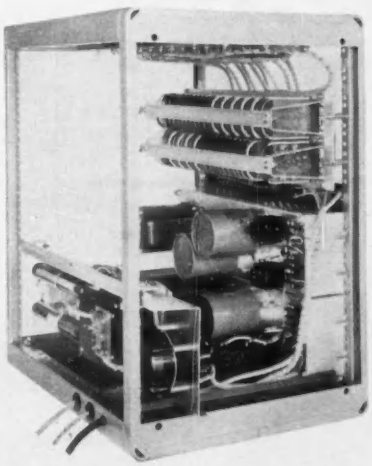


FIG. 34. Computer Control Co. used their transistorized logic to construct this winder control for General Tire and Rubber.

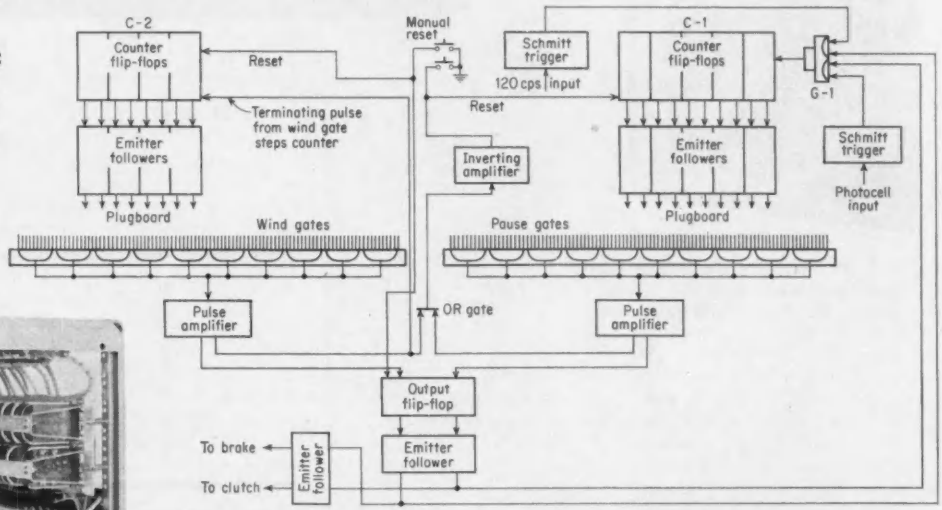


FIG. 35. Simplified diagram of ball winder.

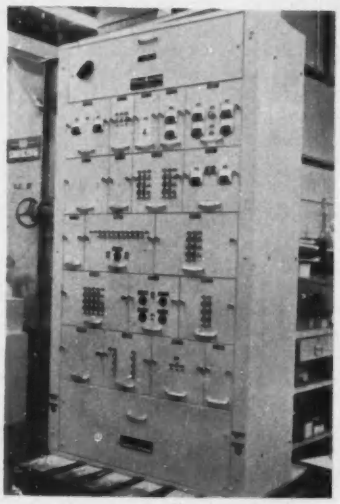


FIG. 36. Directo-Matic control system by GE decides when to stop uncoiler.

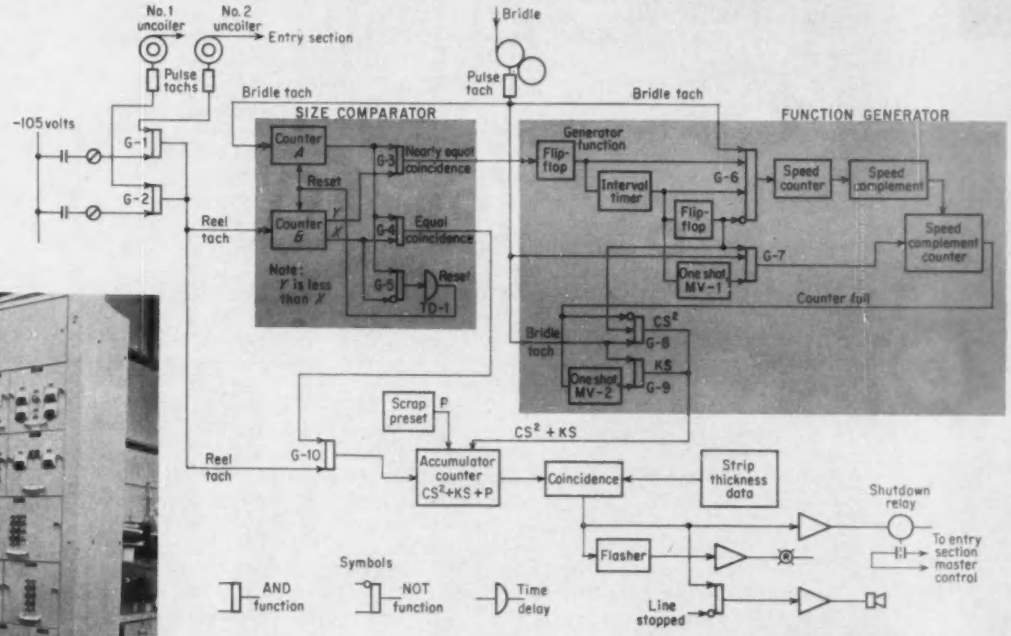


FIG. 37. Entry section controller can be operated manually, but only the automatic mode is considered here.

phase the brake is applied and the gate controlling the 120 pps signal is enabled, passing these pulses to counter *C*-1. All outputs from this counter are buffered by emitter followers and brought out to a plugboard. Here they may be plugged into the input of the 10 wind and 10 pause gates arranged in alternating sequence across the bottom of the board. Outputs from the counter can be plugged into the pause AND gates to select any pause length from 2/120 to 19/120 sec. When the proper count is reached the gate passes a signal which is amplified by a pulse amplifier and used to reset the output flip-flop. This resets the brake and energizes the clutch through two cascaded emitter followers used for power amplification. An output from the pulse amplifier is inverted and resets counter *C*-1 for the next operation.

Setting the clutch also enables gate *G*-1 to pass the photocell input. Counter *C*-1 now counts oscillations of the winder and its outputs are plugged into a wind gate on the plugboard to select a number of oscillations from one to nine. When this number is reached there is an output from a wind gate which is amplified by a pulse amplifier, setting the output flip-flop, resetting counter *C*-1, and signalling counter *C*-2. If it were not for *C*-2 the cycle would be repeated.

Outputs from counter *C*-2 are also buffered and are used to select one of the wind or pause gates. In this manner the wind and pause gates are selected in sequence allowing a different number to be programmed from counter *C*-1 for each different gate. Each time a terminating pulse is derived from a wind gate counter *C*-2 steps to the next gate allowing the selection of 10 different wind and pause cycles. Use of the wrong set of gates is prevented by holding off all pause gates when the brake is off, and holding off all wind gates when the clutch is off. In this way an easily changed winding sequence can be programmed on the plugboard.

6. *Annealing line entry section control*

High operating speed plus the need for extreme reliability dictated the choice of transistor logic in General Electric Co.'s controller for the entry section of a continuous annealing line at the Fairless Works of U. S. Steel. To keep the line operating continually as the end of a coil approaches, the following sequence of events takes place. The looper tower, which acts as a dynamic store to provide a continuous flow of strip to the line, is filled if it is not already full. The entry section is brought to a stop with a small number of wraps still on the coil. The old coil is cut off,

the end is welded to a new coil, and the new coil is brought up to speed to feed the line.

The function of the transistor logic Directo-Matic control panel in Figure 36 is to stop the entry section with a minimum number of wraps (between three and 15) remaining on the uncoiler. The number of revolutions of the uncoiler during stopping goes up as the square of the entry speed based on a constant entry deceleration. This then is one of the three functions that must be taken into account in determining when to stop the entry section. The other two are the thickness of the strip and the number of wraps to be left on the uncoiler (scrap preset). Allowing a few wraps to remain on the uncoiler when it is stopped holds the scrap end out of the process and provides margin for system errors.

In the simplified block diagram of Figure 37 the signals from the pulse tachometer on the uncoiler being used and the tachometer on the bridle are compared by the size comparator. When the coil reaches a predetermined diameter these two signals will have the same pulse rate. The comparison to determine when this size has been reached is done by counting the two signals in counters *A* and *B* until counter *A* overflows. The first overflow pulse then probes gates *G*-3 and *G*-4 to check for coincidence. If counter *B* does not contain as many counts as *A* when *A* overflows, gate *G*-5 passes the overflow pulse to time delay unit *TD*-1 which resets both counters. This counting sequence then repeats until counter *B* contains nearly as many counts as *A*. At this point gate *G*-3 passes the overflow pulse to the function generator section which computes the necessary data to shut down the line. On a counting cycle subsequent to the generation of a nearly equal signal, counter *B* will contain at least as many counts as *A*. This will open the equal coincidence gate and initiate shutdown.

At nearly equal coincidence it is necessary to generate two signals that are functions of speed. The first is the number of wraps required to stop the drive—equal to a constant times speed squared (CS^2). The second is the number of wraps removed between the time the shutdown signal is generated and the drive begins to slow down—equal to a constant times speed (KS). These two signals are produced by the function generator on command of the "nearly coincidence" signal. This signal triggers a flip-flop which in conjunction with an interval timer enables gate *G*-6. This gate then passes the pulses from the bridle tachometer to the speed counter for a period determined by the interval timer, after which a second flip-flop is triggered by the timer, cutting off *G*-6 and stopping the count.

At this point the speed counter contains a count proportional to bridle speed, and, since this measurement was made when the coil was a given diameter, it is also proportional to uncoiler speed. The complement of the number stored in the speed counter is now set into the speed complement counter and gates *G*-7 and *G*-8 are enabled. Gate *G*-7 passes pulses from the bridle tach to the speed complement counter and *G*-8 to the accumulator counter. The length of time *G*-8 is open depends on the time it takes to overflow the speed complement counter. And since it was initially preset to the complement of the speed, this time will be proportional to speed and the number of pulses passed by *G*-8 will be proportional to speed squared. When the speed complement counter overflows it disables gate *G*-8 and triggers one shot *MV*-2. This enables gate *G*-9 for a given time interval, adding a signal to the accumulator proportional to speed. Before starting, the output of scrap preset *P* set the accumulator to a number proportional to the number of wraps to be left on the uncoiler.

The accumulator counter now contains all the necessary information. The number of wraps still to be removed from the reel after equal coincidence is the difference between the strip thickness and the data in the accumulator counter (times a constant). Therefore, after the size comparator coincidence, the output of the uncoiler pulse tachometer is added to the accumulator counter and at the strip thickness preset, the shutdown signal stops the entry section.

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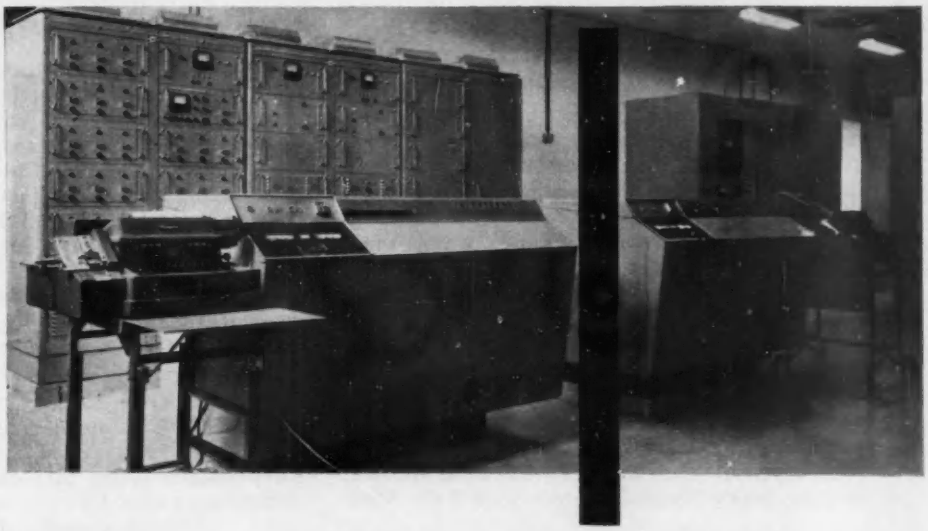


FIG. 1.
Two computers guard nuclear reactor.

Digital Computers Monitor Nuclear Steam Generator

THE GIST: The Chinon nuclear power plant of Electricite de France uses a gas cooled reactor with heat transfer from the carbon dioxide coolant to raise steam that drives turbine generators. Each of the reactor's 1,148 fuel cartridges, totalling 140 tons of natural uranium, has a magnesium alloy cladding. Because these elements operate near their critical temperatures, a great possibility exists that the cladding may crack and thereby release radioactive fission gas into the cooling system.

Circulating fission gas in the coolant can permanently contaminate the reactor. Major splits in the cladding are simple to detect. Pinhole leaks, however, are not immediately obvious; often formation of uranium oxide reseals the holes, but eventually an accumulation of several adjacent pinholes can lead to a major cartridge split. Timely detection of pinhole leaks as they occur is therefore of utmost importance, and this is accomplished by a duplex digital computer system, Figure 1, that directs the scanning, detection, and computation of the radioactivity in the 1,148 coolant channels around the fuel slugs.

J. AURICOSTE, R. CHAMBOLLE, Y. PANIS, and J. PRADES
Compagnie Europeenne d'Automatisme Electronique (formerly Intertechnique), France

In the Chinon nuclear power reactor each fuel cartridge hangs from a hook inside its vertical channel through which coolant gas flows. From the 1,148 channels small monitoring pipes bleed off some coolant gas for analysis. In its simplest form, reactor monitoring consists of the digital computer system selecting a sample from one channel group of four adjacent channels, directing the sample through a complex valve arrangement to a coarse scaler (or precipitator) in which two radiation measurements are made, and from these measurements calculating the fission gas activity change rate. To simplify system description the actions of sample selection, fission detection, and activity calculation—which are interrelated—will be discussed separately.

Selecting samples for analysis

Each four-channel group is monitored for 1 min in every 24. To cover all 287 channel groups in this 24-min period requires assigning 24 channel groups to time-shared coarse scalers, of which there are 12 operating simultaneously as shown in Figure 2, top diagram. The channel groups are sequentially

scanned by computer direction, a code designating for each channel group both the coarse scaler to which it is assigned and the position of its monitoring period within the 24-min cycle. Thus channel group designation 0815 means monitoring occurs during the 15th minute on number 8 coarse scaler. Two spare coarse scalers are provided which can be switched in to replace any of the 12 normal ones.

The lower diagram in Figure 2 indicates the synchronization of the rapid, fine monitoring which is initiated when a burst slug or leak is detected. Here, when a channel group contains excessive fission activity in its sample, the computer automatically switches that channel to fine scaling. A fine scaler then monitors the four constituent channels of that group, and each channel is monitored for 1 min of a 4-min period. Synchronizing the coarse and fine scanning cycles, Figure 2, insures six full fine scanning cycles occurring in one coarse scanning cycle.

THE SAMPLING PROCEDURE

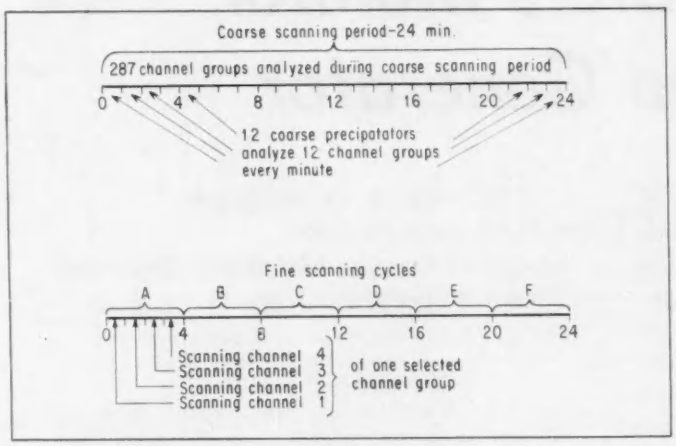


FIG. 2. Synchronizing coarse and fine scaling.

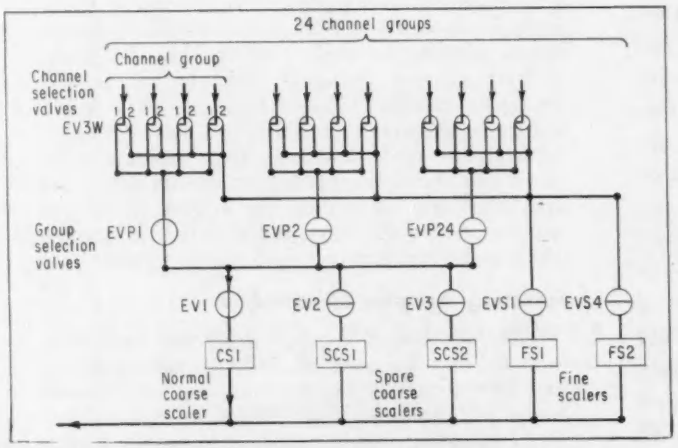


FIG. 3. The computer directs complex solenoid valve system.

Figure 3 contains a simplified schematic of how a complex solenoid-operated valve system switches gas samples from 24 channel groups to one precipitator. For the reactor there are 12 such systems operating simultaneously. Input signals to the electrovalves come from a timing unit and relay registers in the RW-300 digital computer outputs. Gas sample inputs flow through the 96 three-way electrovalves designated *EV3W1* to *EV3W96*, and the samples are switched either to the coarse scaler on position 1 or to one of four fine scalers on position 2.

Timing signals operate the group selection valves *EVP1* to *EVP24* at times corresponding to the position of the channel group monitoring period within the 24-min period. The selected channel-group sample passes into the coarse scaler *CS1* through open valve *EV1*. However, if a spare coarse scaler is needed, *EV1* closes and either *EV2* or *EV3* opens.

During fine scanning of a channel group, computer signals close all group selection valves *EVP1* to *EVP24* and open one fine scaler valve *EVS1* to *EVS4* to couple one of the four fine scalers to the appropriate channel group outlet line. Each channel in the channel group is sequentially connected to the outlet line by computer direction of selector valves *EV3W1* to *EV3W4*. A system limitation is that only one channel group in each of the 12 24-channel groups can be switched to fine scanning. Otherwise gas samples from different channel groups would mix in the common scaler input line. However, warning alarms will sound if the computer inadvertently switches two channel groups to fine scaling from the same 24-channel group arrangement.

Fission detection

Coolant gas always contains some radioactive elements whose activity level depends on reactor power level and channel location. To find fission gas activity G requires two measurements on each sample. The first is the coolant absolute activity level *B*. The second measurement $(B + G)$ combines the count of the absolute activity level as well as the fission gas activity due to the rubidium and cesium atoms in the fission gas. Then the fission gas activity itself is $G = (B + G) - B$.

Special rotary precipitators developed by the French Atomic Energy Commission carry out the two measurements for each channel, with one precipitator good for 24 channel groups. The precipi-

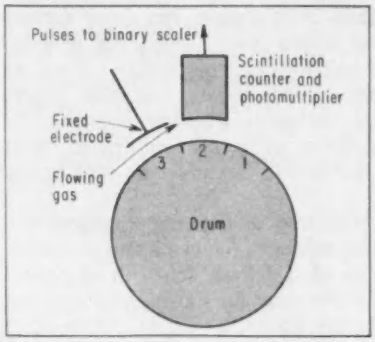


FIG. 4. Precipitator measures fission activity level.

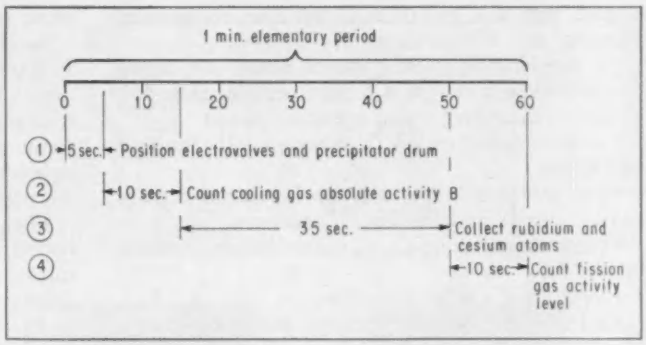


FIG. 5. Precipitator cycle for measuring fission gas activity level.

tator is shown in Figure 4. The polished aluminum drum rotates in 15-deg steps, dividing the circumference into 24 sectors. Other components of the coarse scaler include the fixed collection electrode and the scintillation counter and photomultiplier. To prevent loss of coolant gas, the drum is sealed and operated at 360 psi coolant pressure.

During coarse scaling, timing units program the required drum sector into various positions. Description of the 1-min measurement cycle is simplified by referring to the timing diagram in Figure 5. The initial 5 sec is used to actuate the appropriate electrovalves and position the precipitator drum into position 2. Here, cooling gas absolute activity B is counted for 10 sec. Then, the drum sector moves into position 3 and during a 35-sec interval the application of plus 5 kv on the fixed electrode repels the rubidium and cesium atoms into the drum. In the final 10-sec period, the sector returns to position 2, and a count is made of the absolute activity plus the rubidium and cesium fission gas activity. The 1-min monitoring period completed, the sector is deactivated by applying a minus 2 kv bias to the electrode while the drum again advances to position 3 for the next channel group. The computer inputs are staggered by 5 sec so that during the first 5 sec of the cycle the $(B + G)$ value of the preceding cycle is read out. During the 35-sec interval the computer reads the B values of the present cycle.

Computing the data

Precipitator measurements give the fission gas level G from the difference between background level and absolute coolant activity. Even with no slug fractures or pinhole leaks some fission gas is always present in the coolant, the fission activity increasing with the reactor power output. These variations mean that the fission gas activity change rates E have to be used as the monitoring quantity. To evaluate this change requires establishing both a reference level G_0 at a given time and also a constant α proportional to over-all reactor activity. The fission activity change rate is:

$$E = G - \frac{\alpha G_0}{\alpha_0}$$

where α is the activity factor during the measurement cycle and α_0 its value during the reference cycle. The factor α is measured by mixing gas samples from all 1,148 channels and measuring the fission activity G_α of the sample on a separate precipitator. Comparing over-all sample activity G_α to its activity during the reference cycle G_{α_0} gives:

$$\alpha = G_\alpha / G_{\alpha_0}$$

Four separate cycle operations provide the computer with its calculation constants:

- the over-all reference level of G_0/α_0 for each of the 287 channel groups is obtained by holding constant the reactor activity for a 24-min scanning period. The cycle is initiated by the operator, with the results being stored in the computer.
- new values of G_0/α_0 for any of the 24 channel groups associated with a particular coarse scaler are also initiated by the plant operator. After he specifies the scaler number, the 24-min scanning cycle updates the previously stored 24 G_0/α_0 for that scaler.
- two automatic reference cycles provide new G_0/α_0 values when channel groups are either coupled to their fine scalers or switched back to coarse scanning. On switching to fine scaling, the 4-min cycle determines the G_0/α_0 reference values for each channel in the four-channel group. Switching back to coarse scanning initiates a 1-min cycle determining a fresh G_0/α_0 value and inserts it into the store.

Actual computations of fission activity G, fission change rate E, and reactor constants α are simple arithmetic operations. Logic decisions operate the system changeover from coarse to fine scanning and also initiate signal warning and emergency alarms. All decisions are from equations of the type:

$$A = G - E_p \alpha \frac{G_0}{\alpha_0}$$

where different values of E_p (a function of fission

change rate E) are used to set the changeover, warning, and alarm values.

At the Chinon nuclear power plant, the digital computer-logger system will thus perform these operations during each 1-min operating period:

- scan 12 coarse scalers (and occasionally the four fine scalers)
- compute fission gas activity G, fission activity change rate E, and the reactor constants
- compute and store G_0/a_0 values during reference cycles
- log E_p and a reference values
- actuate the electromechanical switching system from coarse to fine scaling
- compute the warning and alarm levels and actuation of associated signals.

The procedure by which these and other operations are accomplished is summarized in the general computer program, Figure 6. The computer itself must, of course, have the appropriate inputs and outputs, which are described next.

Computer inputs

All input signals are in digital form supplied from electronic signals or from relay contacts. Grouped into input lines of 18 on-off signals, each input line is scanned under program control by fast input switching in the computer. Maximum input to the computer is 32 such input lines coming from:

Electronic binary scalers that count the pulses from the precipitator units. These 1-microsec pulses occur stochastically with a mean frequency varying between 125 and 16,000 pps. Each scaler contains 19 flip-flops: 18 bits for counting and one for overflow. The overflow flip-flop gates the scaler input, stopping the count once an overflow occurs. The computer reads the overflow bit and the 17 most significant bits and resets the scaler to zero before the next count.

The *timing unit*—one of the main parts of the system, comprising an electronic clock and electronic and relay circuitry—that delivers four sets of control signals: 1) to the computer for starting the scanning cycles and the binary scalers, 2) to the precipitators for positioning the drum, 3) to the binary scalers for counting during two given periods of 10 sec in the 1-min cycle and for resetting, and 4) to the electrovalve system for actuating the 24 channel group selector valves for 1 min in 24, and occasionally actuating the channel selection valves as needed for fine scanning.

The *control panel* that carries a series of pushbutton switches with which the operator feeds orders into the computer. Each pushbutton actuates a relay system delivering an on-off signal to the computer. The signal is on when an order is given and the computer resets the relay system after the order has been executed.

The *digital clock* that provides hour and minute information to the computer in binary form.

The *electrovalve system* that delivers information from relay contact registers $R2$, $R3$, and $R4$.

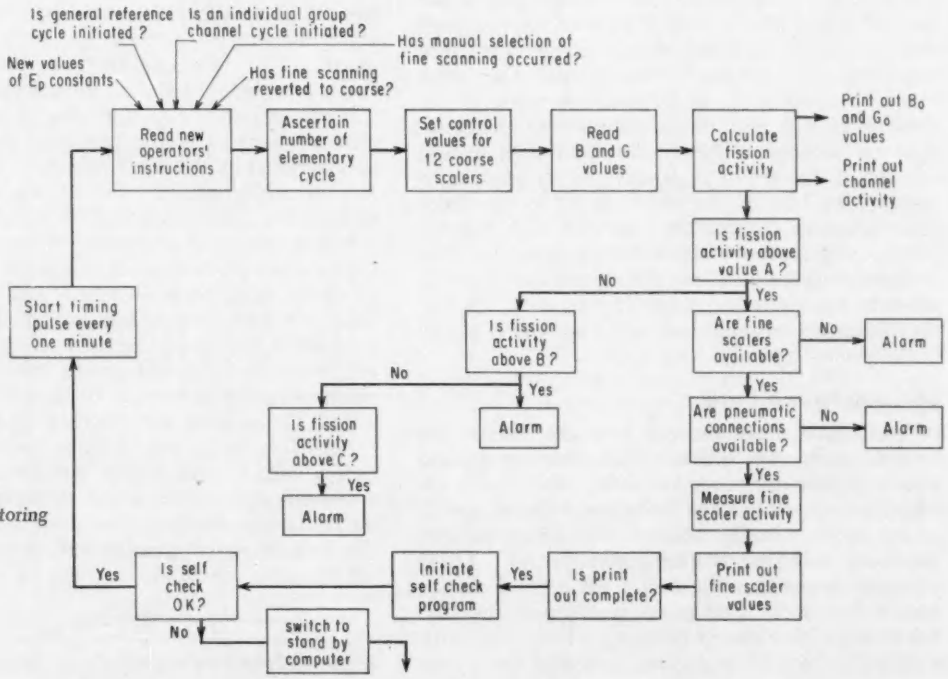


FIG. 6.
General computer program for monitoring nuclear reactor.

The *Flexowriter* that inserts the manual inputs, feeds the E_p constant values from punched tape into the computer store, and also prints out selected failure indications.

Computer outputs

The output mode of the RW-300 computer is by holding relays, the contacts of 18 relays being grouped in an output line. Each output line is actuated under program control by a fast electronic output switching system. The 18 relays of a line may be actuated simultaneously or sequentially. These holding relays actuate the following outputs:

Logging typewriters that print out fission rate change and reference values, the numbers being decoded from the computer binary-decimal output in a separate decoder.

Conventional recorders that trace the fission rate change values on any or all channels switched to fine scan. Each potentiometric recorder is controlled from an adjustable input resistor whose value is set via a digital to analog converter from the computer binary output.

The *electromechanical system* that receives information from the computer through the relay register *R*1 when switching from coarse to fine scanning.

Alarm signals to alert the operator that are each actuated by an output relay.

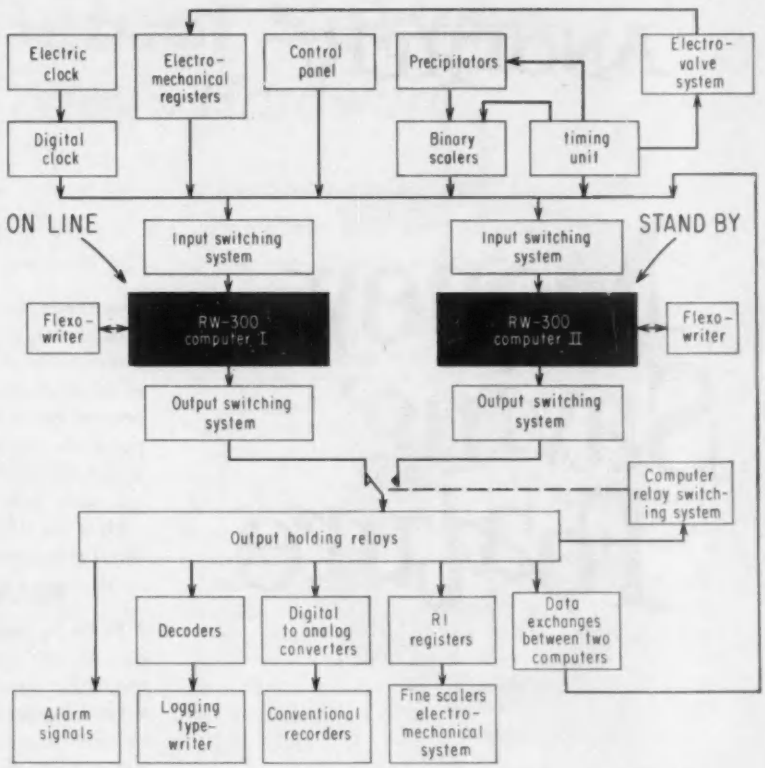


FIG. 7. Two computers improve system reliability.

System reliability

To assure maximum safe operation for the nuclear reactor, two digital computers have been assigned to increase system reliability. As shown in Figure 7, each computer connects to all input devices; but only one computer, the driving computer, actuates such outputs as logging typewriters, alarm signals, and the electromechanical system. Should a failure occur in the driving computer, relays switch output signals from this computer to the standby computer.

In each computer a self-checking program further improves reliability. Start of the self-check program closes a 10-sec time relay. If the check program of the driving computer is not completed in this time span, then the standby computer automatically switches on line.

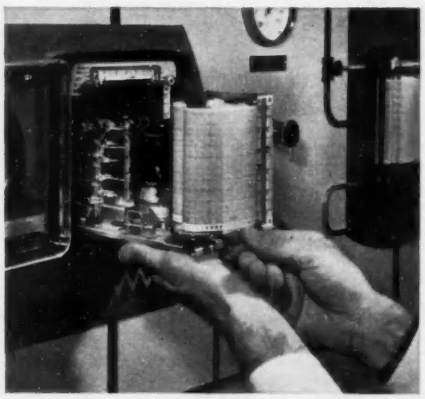
Whenever reference cycle checks are performed, the fission values calculated by the driving computer are punched onto Flexowriter tape. Thus updated data is always ready in case of an emergency changeover. Output relays on the driving computer provide information directly to the standby computer at the end of each elementary cycle as to interconnection status of the channel groups and fine scalers. During an emergency, changeover requires only a 1-min break in monitoring during which time the reference-value tape feeds data into the standby computer.

An automatic over-all systems check inserts a known-strength radioactive source into the precipitator to prove the precipitator, input switching circuits, and computer as an entity.

REFERENCES

1. *EDF-1 BURST SLUG DETECTION SYSTEM*, P. Dive, EDF course on nuclear reactors, June 1959.
2. *GENERAL PRINCIPLES OF THE EDF-1 BURST SLUG DETECTION SYSTEM*, P. Dive, J. Pupponi, J. Spetebroot, Internal Document, Electricite de France.
3. *BURST SLUG DETECTION SYSTEMS*, Y. Amram, Document No. 067AYA, French Atomic Energy Commission.
4. *"EVOLUMETRE" OF THE G3 REACTOR; EXTENSION TO OTHER REACTORS*, Goupil, Megy, Roguin. French patent No. 1,185,212.

ANOTHER Money Saving Feature OF *Taylor Instruments*



"PLUG-IN" CONVENIENCE

Pioneered by Taylor ten years ago, the "plug-in" idea applies both to complete instruments and to components. For example, TRANSCOPE® Controllers plug-in to the backs of Recorders and Indicators and component parts plug-in to main assemblies. It is a dependable design feature of both the pneumatic and the electronic lines of TRANSCOPE instruments, proven by ten years' field experience.

Here are some of the important ways you benefit from this Taylor feature:

PLUG-IN INSTRUMENTS

- **Faster installation** — because housings with manifolds can be installed and connected while recorder and controller mechanisms are being manufactured.
- **Interchangeability of instruments** — a recorder can be quickly substituted for an indicating receiver when process trends need to be studied.
- **Minimum process interruption** — because a faulty instrument can be replaced in seconds.
- **More efficient maintenance** — instruments that require servicing can be taken to the shop, where complete facilities are available. This also means fewer highly skilled personnel are needed.

PLUG-IN COMPONENTS

- **Continuous control,** even when any one of the major assemblies is removed from the electronic recorder or controller, or the pneumatic recorder.
- **Quick conversion** for use with different primary elements, in the case of the 700T Potentiometer Transmitter. Just plug in the appropriate service "can".

* * *

Plug-in is another example of Taylor engineering ingenuity . . . of attention to detail that saves you money, gives you better process control. See your Taylor Field Engineer, or write Taylor Instrument Companies, Rochester, New York, or Toronto, Ontario.

Taylor Instruments
MEAN ACCURACY FIRST

Incremental Servos
Part IV—Today's Hardware

THE GIST: In this fourth part of his series on incremental servos, the author tabulates pertinent characteristics of most of the commercially available stepping motors, describes certain stepper characteristics, and cites some of the common design features.

S. J. BAILEY
Vitro Corp. of America

The table on the following pages summarizes for the systems designer the important characteristics of stepping motors available today. One characteristic not included is accuracy. This has been omitted because most manufacturers feel that they can build in the accuracy needed for the intended application. Stepper motor manufacturers not listed either failed to respond to two independent inquiries or just recently placed a commercial line of steppers on the market. While some manufacturers offer only a single model others have a much broader line. The table however is not meant as a guide to the extent of any one manufacturer's line; for example, a company with only a single entry in the table may in fact produce a wider line than the company with two or three entries. Multiple entries have been included because the companies volunteered the information and because the difference between models is in most cases significant.

Physical characteristics and power input

Of the twenty-eight models listed, more than two thirds operate on dc pulses. Motors made by Gap Instrument and Superior Electric differ from the rest by requiring commutation of a dc input.

The table also illustrates a wide spread in sizes and input power requirements. Sizes range from 6.5 lb models measuring over 4 in. on each side down to a 1.5 oz Size 5 motor; input power requirements are as low as 0.5 watts and as high as 100 watts. This indicates that hardware is available right off the shelf in most cases, for almost any kind of weapon or industrial application that is consistent with this specialized control philosophy.

Stepping and step characteristics

On close examination of the columns describing the actuating mode (i.e. "Solenoid type" for solenoid actuated and "Number of phases" for phase-pulsed) and the column listing degrees per step, it appears that step size has no significant correlation with the motor type. It should be noted that gearing can reduce step size to almost any practical amount.

The smallest step available at the output shaft of the motor itself is specified by Giannini Controls as 0.1 deg. This low step size is produced by a worm which follows the nominal 15-degree increment ratchet wheel. The largest step listed is the 360-degree increment of the IMC motors. The highest stepping rate is Pace Controls' 800 steps per sec, a rate which implies a microscopic inching toward the command position.

Several motor models (e. g., those of Clary Dynamics, Giannini, and Land Air) are or can be readily made self triggering. This feature is sometimes useful, as for example when automatic homing is required. It should be noted however that any stepper can be adapted to any form of special program stepping by appropriate external circuitry.

Stepping characteristics

Slightly less than half of the motors listed use mechanical detenting, an indexing technique susceptible to extremely high accuracy. Curtiss-Wright, for example, has a position-locking detent which automatically releases during step actuation, thus eliminating load torque reaction during quiescence.

Although electromagnetic detenting requires special damping methods, it must not be assumed that mechanical detenting is always free of bounce. B. A. Wesch Electric has approached the electromagnetic damping problem in a very practical way as illustrated in the AIEE Paper No. DP-57-464. Sigma Instruments motors use a permanent magnet field, and the load analysis and matching charts furnished by the company must be observed for best performance.

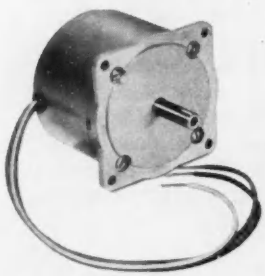
External control

Input circuits for steppers include switches, commutators, transistor triggers, thyratron controls, ring computers, and both vacuum tube and solid state amplifiers. About half the manufacturers listed offer transmitters to program signals to their motors.

Output circuit elements that can be fixed through rigid or resilient attachment to the stepping motors include potentiometers, commutators, data wheels, synchros, resolvers, and many others. Attachment of any load to these low power steppers, however, requires careful dynamic analysis.

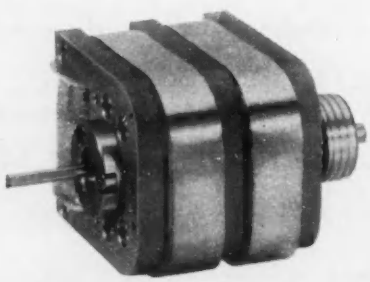
AN UP-TO-DATE SAMPLING OF

MANUFACTURER	PHYSICAL CHARACTERISTICS AND INPUT DATA					
	Model number	Size	Weight	Power req'd	Input type	Control or transmitter available
Anatran Div., Endevco Corp. Pasadena, Calif.	7105	6.3 cu in.	0.3 lb	0.57a @ 28 vdc	Dc pulse	Yes
Clary Dynamics San Gabriel, Calif.	CD700	Size 15	8 oz	15w @ 28vdc	Dc pulse	No
Curtiss-Wright Corp. Wood-Ridge, N. J.	DMA	Size 15	8½ oz	9w @ 28vdc	Dc pulse	No
	DMB	2 in. diam by 3⅝	24 oz	15w @ 28vdc	Dc pulse	No
The Electric Tachometer Corp. Philadelphia, Pa.	RS-295	3 in. sq by 4½ in.	2 lb	10w @ 10-12vdc	Phase commutated	Yes
Electro-Mechanical Specialties Co., Inc. Whittier, Calif.	6000-Series	....	2.5 oz	5w nominal 3-150 vac/dc	Pulse	Yes
Gap Instrument Corp. Freeport, N. Y.	600	4 in. cube	3.5 lb	115vac	Commutated dc	Yes
General Electric Co. Fort Wayne, Ind.	5SMY50HB2	4⅛ in. diam by 4⅝ in.	6.5 lb	360ma @ 38vdc	Dc pulse or square wave	No
	5SMY54HB5	4⅛ in. diam by 5 in.	6.5 lb	270ma @ 115vdc		
Giannini Controls Corp. Caldwell Township, N. J.	8915	2.62 in. diam by 3¼ in.	15-22 oz	1a @ 28vdc	Dc pulse	Yes
	1500C	Size 15	4 oz	0.5a @ 28vdc		Yes
	T786	Size 11	4 oz	195ma @ 24vdc		No
A. W. Haydon Co. Waterbury, Conn.	18100 Series	....	....	140ma @ 28vdc	Double dc pulse	No
IMC Magnetics Corp. Maywood, Calif.	005-801	Size 5	1.5 oz	28vdc	Dc pulse	Yes
	008-801	Size 8	2.0 oz			
	011-801	Size 11	6.0 oz			
	023-801	Size 23	9.0 oz			
Land Air, Inc. Gardena, Calif.	SM300-1	Size 15	7.25 oz	800ma @ 28vdc	Dc pulse	Yes
Ledex, Inc. Dayton, Ohio	D-9191-002	Size 15	13 oz	1.5a @ 28vdc	Dc pulse	....
	D-9191-006	Size 15	13 oz	0.43a @ 85vdc		
	215527	2½ in. sq by 4½ in.	....	380w @ 6-350vdc		
Licon Div., Illinois Tool Works Chicago, Ill.	F2200	2 in. by 2 in. by 2¼ in.	24 oz	65w	Dc pulse	No
McLean Syntorque Corp. Bearsville, N. Y.	15SM45	Size 15	8.6 oz	8.4w @ 28vdc	Dc pulse	No
Pace Controls Corp. Needham Heights, Mass.	M35	3 in. by 6 in. by 3 in.	9 lb	100w @ 115vac	Phase commutated	Yes
Sigma Instruments, Inc. Braintree, Mass.	9AB00	2⅝ by 1½ by 1⅞ in. (Approx.)	10.3 oz	0.5 to 30w @ 150vac	Phase commutated	No
	9AD00	2¼ by 2⅛ by 1⅞ in.	18 oz			
Superior Electric Co. Bristol, Conn.	SS50	3¼ by 3¾ by 3⅞ in.	3 lb	150ma @ 50vdc	Commutated dc	No
	SS150	4¼ by 4¼ by 4¾ in.	6.5 lb	350ma @ 35vdc		
	SS250	4¼ by 4¼ by 4¾ in.	6.5 lb	420ma @ 32 vdc		
B. A. Wesche Electric Co. Cincinnati, Ohio	....	203 frame	....	100w @ 220vac	Phase commutated	Yes



Superior Electric

Curtiss-Wright

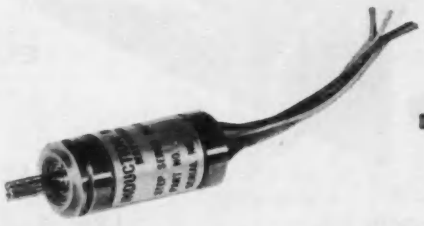


Sigma

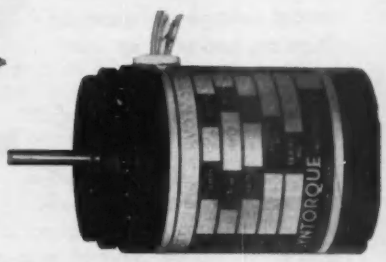
AVAILABLE STEPPING MOTORS

STEPPING AND STEP CHARACTERISTICS					STOPPING AND LOADING		
Solenoid type	Phase-pulsed, no. of phases	Deg/step	Steps/sec	Rotation	Detent type	Load torque	Unit price, $ (depending on quantity)
....	....	180	0-35	Bidirectional	Electromagnetic	1.5 oz-in.	....
Rotary	....	36	30	Bidirectional	Mechanical	2 oz-in.	....
Rotary	....	36	25	Bidirectional	Mechanical	8 oz-in.	125-225
Rotary	....	30	10	Bidirectional		22 oz-in.	175-300
....	3	3 avg	80	Bidirectional	Electromagnetic	5 oz-in.	....
Rotary	....	30, 36, 40	30	Unidirectional	Mechanical	4 oz-in.	62-75
Rotary	....	15	120-150	Bidirectional	Electromagnetic	20 oz-in.	....
....	2	3.75 or 1.875	Approx. 50	Bidirectional	PM armature	150 oz-in.	40
		9.0 or 4.5				75 oz-in.	54
Rotary	....	2	60	Bidirectional	Mechanical	30 oz-in.	166-175
Rectilinear		0.1—6	140		Mechanical	6 oz-in.	475-485
Rotary		90	80		None	1 oz-in.	....
Rotary	....	30	40	Unidirectional	PM field	....	....
....	2	45, 90, 180, or 360	Up to 200	Bidirectional	PM field	0.4 oz-in.	....
						0.8 oz-in.	
						1.8 oz-in.	
						3.0 oz-in.	
Rotary	....	30 or 36	15	Bidirectional	Mechanical	4 oz-in.	100-150
Rectilinear	....	36	15	Bidirectional	Mechanical	3.2 oz-in.	74-98
		36	15			3.2 oz-in.	74-98
		15	15-25			To 4.2 lb-in.	15-25
Rotary	....	15, 18, 20, 30, or 45	20	Unidirectional	Mechanical	2 lb-in.	....
....	4	45	145	Bidirectional	PM field	1.6 oz-in.	152-187
....	3	7.5	800	Bidirectional	Magnetic clutch	35 oz-in.	....
....	2	18	0-400	Unidirectional	PM field	1.15 oz-in.	36-60
				Bidirectional			76-105
....	2	1.8 or 3.6	300	Bidirectional	PM field	50 oz-in.	31-36
						150 oz-in.	38-45
						250 oz-in.	55-65
....	3	60	....	Bidirectional	Electromagnetic	16 oz-in.	....

Ledex



IMC Magnetics



Syntorque

VISIT LAMBDA AT THE IRE SHOW
BOOTHS 2917-18

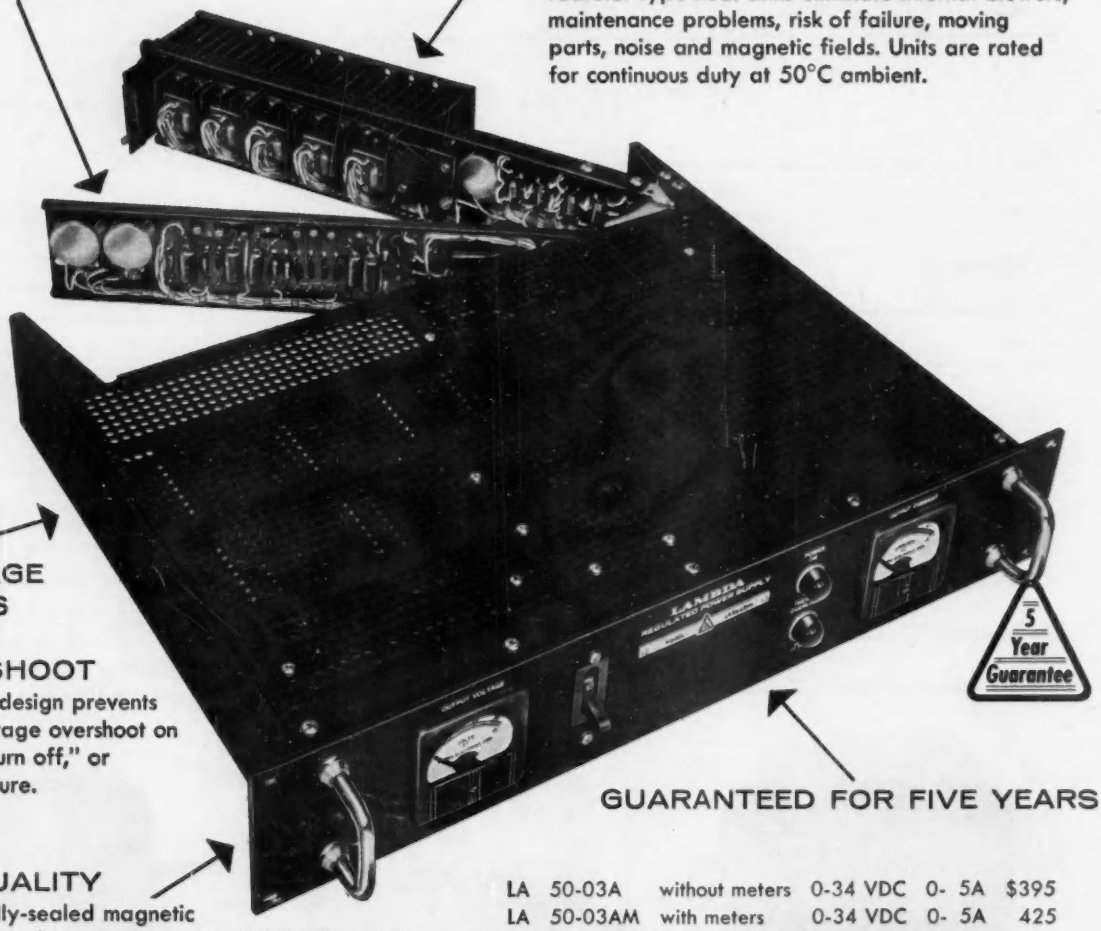
NEW 20 AMP 0-34 VDC Regulated POWER SUPPLY joins

EASY SERVICE ACCESS

Dual-deck, swing-out back construction provides simple and fast service access without the need to remove unit from rack. All major component terminals are accessible from rear.

CONVECTION COOLED— no blowers or filters— maintenance free

Advanced design and special, highly efficient, radiator type heat sinks eliminate internal blowers, maintenance problems, risk of failure, moving parts, noise and magnetic fields. Units are rated for continuous duty at 50°C ambient.



NO VOLTAGE SPIKES OR OVERSHOOT

Lambda's design prevents output voltage overshoot on "turn on, turn off," or power failure.

GUARANTEED FOR FIVE YEARS

MIL QUALITY

Hermetically-sealed magnetic shielded transformer designed to MIL-T-27A quality and performance. Special, high-purity foil, hermetically-sealed long life electrolytic capacitors.

LA 50-03A	without meters	0-34 VDC	0- 5A	$395
LA 50-03AM	with meters	0-34 VDC	0- 5A	425
LA 100-03A	without meters	0-34 VDC	0-10A	510
LA 100-03AM	with meters	0-34 VDC	0-10A	540
LA 200-03A	without meters	0-34 VDC	0-20A	795
LA 200-03AM	with meters	0-34 VDC	0-20A	825

COMPACT
NO BLOWERS

5 AMP 3½" HIGH
10 AMP 7" HIGH
20 AMP 10½" HIGH

PATENTS PENDING

Lambda LA Series Power Supplies are compact, convection cooled and rated for continuous duty at 50°C ambient temperature.

LAMBDA Transistorized 5 and 10 AMP LA Series

COMPLETE SPECIFICATIONS OF LAMBDA LA SERIES (Including improved data on 5 and 10 AMP Models)

DC OUTPUT (Regulated for line and load)

Model	Voltage Range[1]	Current Range[2]	Price
LA 50-03A	0-34 VDC	0- 5A	$395
LA 50-03AM	0-34 VDC	0- 5A	425
LA100-03A	0-34 VDC	0-10A	510
LA100-03AM	0-34 VDC	0-10A	540
LA200-03A	0-34 VDC	0-20A	795
LA200-03AM	0-34 VDC	0-20A	825

[1]The output voltage for each model is completely covered in four steps by selector switches plus vernier control and is obtained by summation of voltage steps and continuously variable DC vernier as follows:

MODEL	VOLTAGE STEPS
LA 50-03A, LA 50-03AM	— 2, 4, 8, 16 and 0-4 volt vernier
LA100-03A, LA100-03AM	— 2, 4, 8, 16 and 0-4 volt vernier
LA200-03A, LA200-03AM	— 2, 4, 8, 16 and 0-4 volt vernier

[2]Current rating applies over entire output voltage range

Regulation (line) .... Better than 0.05 per cent or 8 millivolts (whichever is greater). For input variations from 100-130 VAC.

Regulation (load) ... Better than 0.10 per cent or 15 millivolts (whichever is greater). For load variations from 0 to full load.

Transient Response (line) ..... Output voltage is constant within regulation specifications for step function line voltage change from 100-130 VAC or 130-100 VAC.

Transient Response (load) .... Output voltage is constant within regulation specifications for step-function load change from 0 to full load or full load to 0 within 50 microseconds after application.

Internal Impedance ... LA 50-03A less than .008 ohms
LA100-03A less than .004 ohms
LA200-03A less than .002 ohms

Ripple and Noise ..... Less than 1 millivolt rms with either terminal grounded.

Polarity ..... Either positive or negative terminal may be grounded.

Temperature Coefficent ..... Better than 0.025 %/°C

AC INPUT..... 100-130 VAC, 60 ± 0.3 cycle[3]
LA 50-03A . . . 360 watts[4]
LA100-03A . . . 680 watts[4]
LA200-03A . . . 1225 watts[4]

[3]this frequency band amply covers standard commercial power lines in the United States and Canada.
[4]with output loaded to full rating and input at 130 VAC.

AMBIENT TEMPERATURE AND DUTY CYCLE..... Continuous duty at full load up to 50°C (122°F) ambient.

OVERLOAD PROTECTION:

Electrical ..... Magnetic circuit breaker front panel mounted. Special transistor circuitry provides independent protection against transistor complement overload. Fuses provide internal failure protection. Unit cannot be injured by short circuit or overload.

Thermal ..... Thermostat, manual reset, rear of chassis. Thermal overload indicator light front panel.

INPUT AND OUTPUT CONNECTIONS..... Heavy duty barrier terminal block, rear of chassis. 8 foot, 3 wire detachable line cord.

METERS..... Voltmeter and ammeter on metered models.

CONTROLS:

DC Output Controls .. Voltage selector switches and adjustable vernier-control rear of chassis.

Power ..... Magnetic circuit breaker, front panel.

Remote DC Vernier ... Provision for remote operation of DC Vernier.

Remote Sensing ..... Provision is made for remote sensing to minimize effect of power output leads on DC regulation, output impedance and transient response.

PHYSICAL DATA:

Mounting ..... Standard 19" Rack Mounting

Size	LA 50-03A	3½" H x 19" W x 14⅜" D	
	LA100-03A	7" H x 19" W x 14⅜" D	
	LA200-03A	10½" H x 19" W x 16½" D	
Weight	LA 50-03A	55 lb Net	85 lb Ship. Wt.
	LA100-03A	100 lb Net	130 lb Ship. Wt.
	LA200-03A	140 lb Net	170 lb Ship. Wt.

Panel Finish ..... Black ripple enamel (standard). Special finishes available to customers specifications at moderate surcharge. Quotation upon request.

Send for complete Lambda Catalog.

LAMBDA ELECTRONICS CORP.
515 BROAD HOLLOW ROAD, HUNTINGTON, L. I., NEW YORK 516 MYRTLE 4-4200

CIRCLE 137 ON READER SERVICE CARD

LA116

FIG. 1. British Railways Margam marshalling yards (right). In front are two primary retarders; behind them are eight secondary retarders. Console shows operators status of switching and alarms. Tower also contains test equipment.

The Modern Automatic Classification Yard

R. M. FOULKES
Associated Electrical Industries
–G.R.S. (Manchester) Ltd.

A new electronic freight yard illustrates how equipment for the automatic classification of cars has improved since the concept of the automatic yard was introduced just six years ago.

Until six years ago, the railroad freight car classification yard was the province of the veteran switchman, a leathery-faced, cold eyed individual who had learned over the years to estimate the speed of a rolling freight car at a glance and then to apply about the right amount of braking. In 1954, the Union Pacific Railroad introduced automatic classification at its North Platte, Nebraska yards (CtE, January 1955, p. 29). That first system, considered a complex electromechanical computer control innovation then, is dwarfed by today's electronic classification schemes. Typical of the extent of progress since that pioneering installation is the new automatic classification yard of British Railways at Margam, South Wales.

Although the equipment has changed radically in the past five years, the automatic classification problem is still the same. A freight train with cars bound for many different destinations enters the yard. The train has to be dismembered, the cars shifted to form new trains bound for the proper cities. To do this, the entering train is backed up a rise, called a hump, the cars are uncoupled one at a time so they coast down the far side of the rise and are switched to the proper track. The shifting

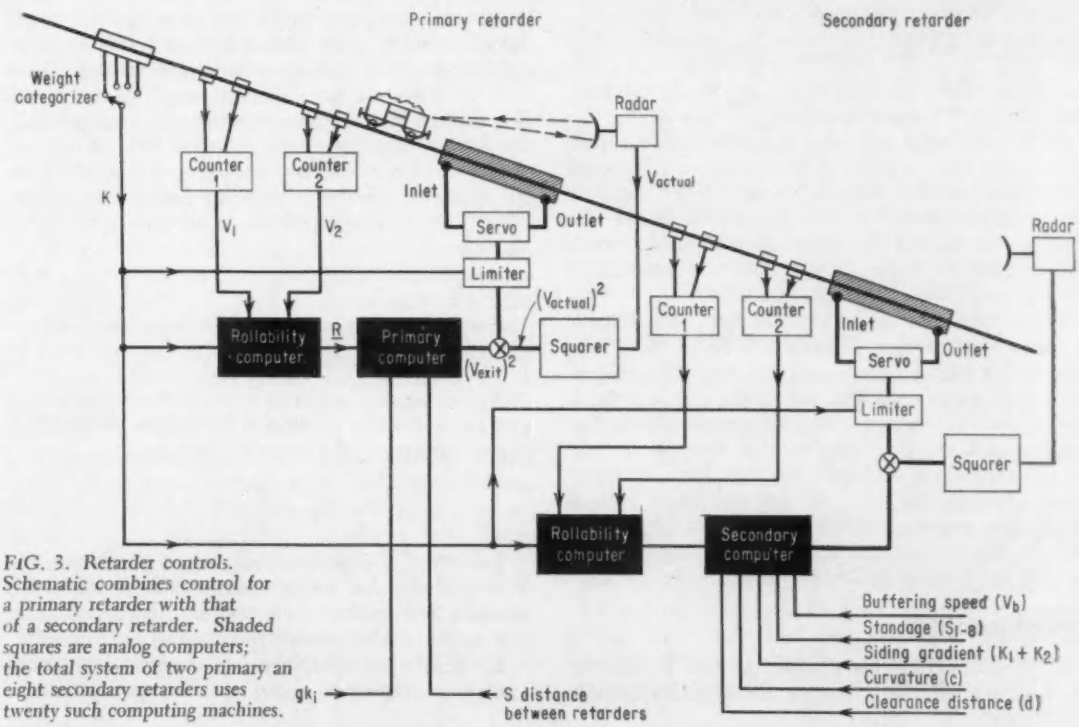


FIG. 3. Retarder controls. Schematic combines control for a primary retarder with that of a secondary retarder. Shaded squares are analog computers; the total system of two primary an eight secondary retarders uses twenty such computing machines.

must be accomplished with a minimum of bumping cars to prevent damage to the goods in transit.

Railroads turned to automatic classification to reduce this damage. The veteran switchman's estimate is frequently off a trifle, just enough to send a humped car crashing resoundingly into a standing car. Ideally, each car should coast down the hump at constant speed, but because the cars are different, some accelerate so rapidly they smash into cars already on the track, while others stall midway down the hump and have to be pushed the rest of the way by a switch engine. Thus, the classification problem has two aspects: 1) how to switch a car to put it on the proper track, and 2) how to control its speed so that once on the right track, it does not smash into others already positioned.

Switching control

In Union Pacific's original installation, a unique electromechanical memory programmed switching. Glass and metal balls rolled through the device tripping limit switches in a simulation of the arrangement of the switches in the yard. The installation at Margam uses a punched tape programmer.

At Margam, a car leaving the hump passes through a maximum of six switches on its way to the final sorting sidings. A six-digit binary code, with each digit defining one switch position, identifies the route. Track circuits, one for each switch, prevent switches from operating while a car is passing and pass the destination code to switches ahead of the car as it travels down the hump.

A punched tape containing car details and siding destination controls the routing. Associated with each track circuit is a route storage circuit that stores the destination codes before passing the information onto the next storage circuit in the car's route.

At the start of a switching operation, all the track circuits are unoccupied. A frequency superimposed on the correct dc track circuit signals the engineer to start the operation. As the engine backs the train up the hump, the punched tape reader sends the destination code of the first car sequentially through each switch storage circuit.

When that first car enters the first track circuit, its associated storage circuits disengage from the tape reader which then reads and codes the second car's destination. As the car leaves the first track circuit, the first storage circuit is reconnected to the reader which can then feed in the destination code for the second car and reset the switches. As a car passes through the track circuit associated with a switch, the passage cancels the current destination code in the storage circuit for that switch, making it ready for the coding of the next car.

Speed control

In its pioneering installation, Union Pacific set the tone for what has become the classic approach to speed control in automatic classification. It determined the acceleration of a car as it coasted down a sample section of track, thus obtaining a measure of the forces of gravity, friction, and wind; computed with an analog computer what the velocity of the car should be at specified points on its route; measured the actual speed of the car during its descent—with a radar speed meter at North Platte; and continuously compared computer speed with actual speed, feeding the error signal to a pneumatic controller which operated track retarders to slow the cars when necessary.

At South Wales, British Railways follows this same general approach. The Margam installation also employs an analog computer—in fact twenty computers—electropneumatic actuators for the retarders, and Doppler radar to make actual speed measurements.

The Margam yard, as seen in Figure 1, has two primary and eight secondary retarders to slow cars to the proper coasting speed. The primary units control coasting speed from the hump so that the time all cars move a fixed distance—from the primary retarders to the secondary ones—is the same. The secondary units control car speed as it moves onto the sorting sidings so that a car impacts one already standing on the sorting siding at a speed less than 4 mph, regardless of how many cars have been positioned previously on the siding.

Primary retarder control

Figure 3 illustrates the analog computer system to control the electropneumatic retarders. The exit speed from the primary retarder varies with each car. Objective of the primary retarder control is to maintain at least one track circuit length between cars so that sufficient time elapses to change track switches. Since distance S, from the primary retarders to the secondary retarders, is the same for all retarders, the exit velocity from the primary units can be expressed in a simple equation of motion:

$$V_p = \frac{S}{t} - \frac{1}{2} at \qquad (1)$$

where t = preset running time between primary and secondary retarders
a = acceleration acting

If this expression is put in terms of track gradient k_1 and the rollability of the car R—factors which affect the acceleration—the equation becomes:

$$V_p = \frac{S}{t} - \frac{1}{2} t\,(gk_1 - R) \qquad (2)$$

Since S, t, and gk_1 are constants, the only variable is rollability. An analog computer determines this variable and feeds it to a second analog computer which then calculates exit speed using Equation 2.

To determine rollability, the change of potential energy is subtracted from the change in kinetic

energy, computed from measurements of car weight and velocity made at two points:

$$R = gk_1 - \frac{K}{2s}(V_2^2 - V_1^2) \qquad (3)$$

where V_1 and V_2 are velocities of the car at points separated by a distance s; K is a weight factor which is constant and compensates for the rotational energy of the wheels and axles.

A pair of inductive detectors placed in front of the retarder measures the velocity. As the first wheel of the car passes the first detector, an induced signal opens the gating circuit of a 1 kc crystal controlled counter. When the wheel reaches the second detector an induced signal stops the count. The resultant count and the separation of the detectors combines to indicate the velocity at that point. A second pair of detectors measures velocity the same way at the second point.

The weight factor is obtained by measuring how much the most heavily loaded axle of a car deflects a special rail length with a slot cut in the web. Precision switches placed in the slot categorize the car into four weight classes. Solving Equation 3 in an analog computer produces the rollability analog voltage that feeds the exit speed computer.

The computed speed V_p becomes the *desired value* signal for an on-off electropneumatic control system that moves the primary retarders. Retarding is performed by squeezing the car wheels between pneumatically operated beams, the pneumatic pressure controlled by electropneumatic inlet and exhaust valves. A 10,000 Mc Doppler radar unit, mounted beyond the retarder exit (Figure 4), measures actual velocity. The measured velocity is converted to an analog proportional voltage and squared before being applied to the retarder servo.

Better accuracy is obtained by maintaining the pneumatic control pressure proportional to the deviation of the squares of the actual and desired speeds. Using the squares helps to offset the effects of the slow pneumatic loop time constant.

To prevent cars from climbing out of the retarder if too high a pressure is applied, the retarder system is weight limited. The weight factor signal from the rail operated precision switches feeds a limiter circuit controlling the maximum deviation signal applied to the on-off servo controlling the airvalves.

Secondary retarder control

Control system for the secondary retarders is similar to that of the primary units with just a few exceptions. For one, additional analog inputs are needed to include consideration of such variables as required buffering velocity, distance from the retarder to the clearance point of the siding, the siding's gradient and curvature, and its unoccupied length. The required buffering velocity is set at 3 mph, approximately midway between the limits of zero and four mph.

Exit velocity from the secondary retarders is computed by an analog device from the expression:

$$V_e^2 = V_b^2 + 2R(d + S_{1\text{-}s}) + C - 2gk_1 d - 2gk_2 S_{1\text{-}s}$$

V_e = exit speed
R = car rollability factor
d = clearance distance
C = curvature
k_1 = gradient in the switching zone
k_2 = gradient in the siding zone
$S_{1\text{-}s}$ = the unoccupied distance of a siding.

As a siding fills up, $S_{1\text{-}s}$ diminishes. Each siding has a standage storage circuit composed of a potentiometer which is preset by siding track circuits. When a car enters a siding, a stepping switch moves the potentiometer slider an amount proportional to the length of the car.

The clearing distance is constant for a particular siding. Routing switches send the proper distance to the analog computer.

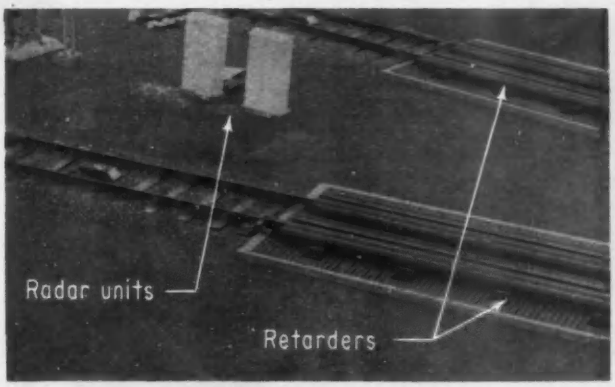
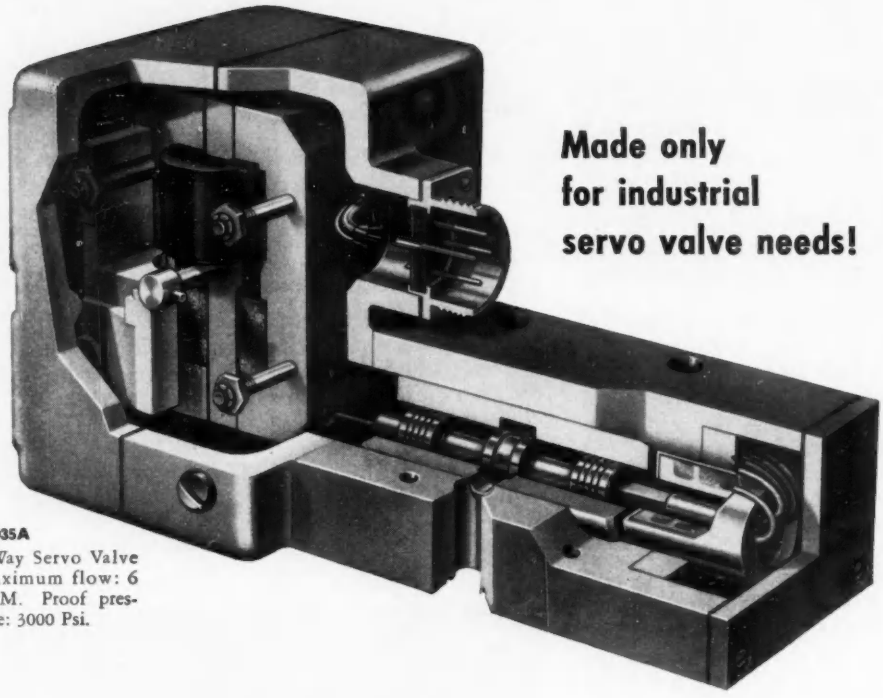


FIG. 4. Radar cabinets sit just behind primary retarders.

One factor that is neglected in this calculation is the rotational energy of the wheels and axles of a car. The rotational energy of a light car is larger than that of a heavier one. A correction is added, however, from the car weight information.

Alarm in the tower

From a glass enclosed room in a three-story tower, operators can watch the automatic classification yard perform its sorting job. Control consoles contain alarm and test circuits that advise the operators if trouble develops. In fact, the equipment not only reports what section of the equipment has failed, but also what capability—fully automatic, semi-automatic, or manual-retarder operations—remain. A test panel in the equipment bay contains facilities for testing release speed and rollability computers. With this equipment, the operators can simulate passage of a car through the retarder to check track circuits and weight detector operation.



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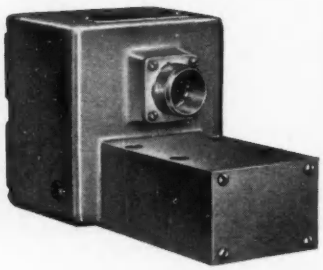
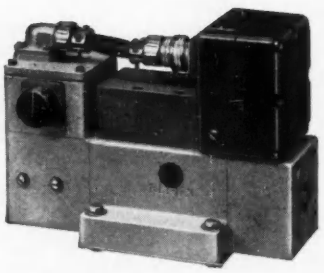
4-Way Servo Valve Available in ranges from 50 cu. in/min. max. to 4 gals./min. max. at 1000 Psi. Proof pressure: 3000 Psi.



V7040A
2-Stage Servo Valve Maximum flow: 40 gallons/minute at 1000 Psi. Proof pressure: 3000 Psi.



V7041A
2-Stage Servo Valve Maximum flow: 15 gallons/minute at 1000 Psi. Proof pressure: 3000 Psi.

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What you can learn from the REGULUS CONTROL SYSTEM

The Regulus missile, a pilotless aircraft for surface-to-surface missions developed for the Navy by Chance Vought, has been operational for some time aboard submarines, cruisers, and guided missile ships. Employing one basic design, Regulus is suitable as a tactical missile, a flight test missile, or a target drone. Author Hardy details the design of the missile's autopilot and stabilization system and describes how some unanticipated difficulties, encountered while converting the design to final, satisfactory hardware, were fixed.

H. S. HARDY, JR.
Chance Vought Corp.

The Regulus missile has swept back wings, one vertical fin and rudder, and no horizontal tail surface. Pitch and roll control is accomplished by a pair of ailavators mounted on the wings' inboard trailing edges. The missile is 33 ft long with a 21-ft wing span, and weighs about 12,000 lbs. Regulus I has a range of 500 nautical miles at transonic speeds with a high cruise altitude. Two auxiliary boost-rockets facilitate launching. After launching, the missile's autopilot moves the ailavator surfaces to bring the missile to a preset climb attitude. A profile system gives a completely controlled flight from launch to touchdown for a flight test missile or a target drone; launch to termination for a tactical missile.

When the Regulus design program started in 1947 there were no autopilots available that had controlled any transonic-speed aircraft. A study of autopilot systems for lower-performance manned military and commercial aircraft showed that none could be used for the pilotless Regulus without extensive modification to improve performance and reliability. However, prior work on autopilots and stabilization did provide a solid foundation on which to evolve the Regulus system.

What Regulus control does

The Regulus missile control system's primary function is stabilization in conjunction with steering the missile. The autopilot closes the loop between airframe attitude and control surface motion. Stabilization and steering occurs in three separate control channels, one each for yaw, roll, and pitch—as shown in the figure on the next page. The gyros sense any change in present reference and send a corresponding error signal into the computers. The outputs of each computer are two voltages, one proportional to the input voltage (displacement gain in volts per deg) and the other a function of the rate of change of the input voltage (rate gain in volts per deg per sec). These signals provide synthetic damping for the autopilot-missile combination.

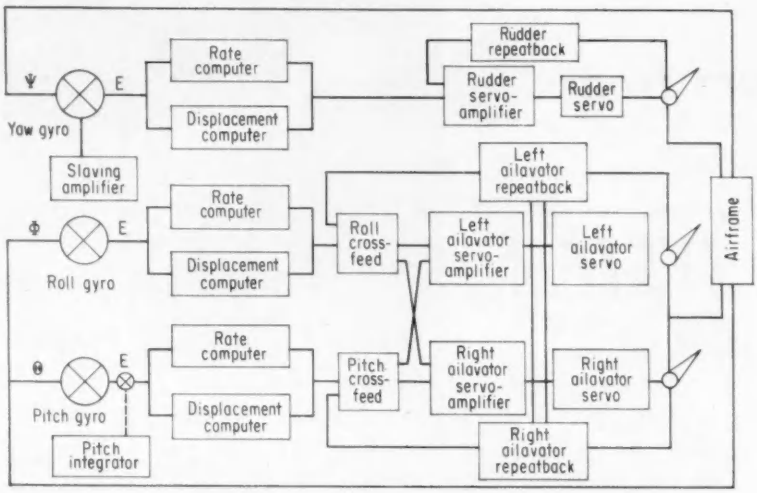
Computer outputs feed into the servosystem. Here, a phase sensitive electronic servoamplifier positions an electrohydraulic servovalve which in turn controls the flow of oil to the control-surface-positioning actuator. The servoloop is closed by a synchro coupled to the surface. The synchro produces a voltage proportional to surface displacement, and the signal is fed back and compared with the input signal.

The roll and pitch channel servosystems differ from the rudder channel servosystem only by the addition of a crossfeed stage. A voltage fed into the pitch crossfeed results in two output signals of the same phase. These signals feed into the right and left ailavator servoamplifiers, producing deflection of the two surfaces in the same direction. A voltage fed into the roll crossfeed results in two output signals but of the opposite phase. These signals feed into the right and left ailavator servoamplifiers, producing opposite motion of the ailavators.

Bank turn commands are achieved by introducing into a slaving amplifier a voltage that torques the yaw gyro. Roll angle is attained by feeding part of the bank turn signal into the roll servo mixer stage. Missile orientation, the introduction of climb phase, constant altitude, letdown, terminal maneuver, and pitch trim commands are functions obtained from the pitch integrator.

The automatic profile control system of the Regulus I missile functions through the pitch integrator and the engine throttle system. An automatic vertical-plane flight profile may be preset into the missile so that the missile will climb to a preset altitude, cruise at that altitude until receipt of a dive or letdown command, and then either dive vertically to impact or let down to a preset low altitude for an automatic low level cruise. Automatic control of landing speed is also available.

During climb and letdown, missile airspeed is maintained by pitch attitude variation, at constant throttle.



REGULUS MISSILE CONTROL SYSTEM

During cruise and landing, airspeed is maintained by throttle variation. Constant altitude is maintained by pitch integrator control of pitch attitude.

The Regulus compass system permits the missile to be launched on any heading and to be turned automatically to a required heading after the missile becomes airborne. Also included are provisions to orient the magnetic compass system in the presence of local magnetic disturbances before launching.

To achieve maximum torque-to-inertia ratios, the missile's servosystem employs hydraulic transmission terminated by piston actuators. Severe storage and operational requirements dictate a closed hydraulic system, allowing no air to come in contact with the hydraulic fluid at any time.

To obtain optimum performance, it was desirable to be able to vary the rate and displacement sensitivities chiefly as a function of airspeed and altitude. However, to do so on a proportional basis would have called for undue complication of the control equipment. Instead, different fixed gains were designed into the system. Originally, four different gains were set into the computer and displacement network for each control channel. The final design settled for two fixed gains in the computer for each channel. These gains, proven to be acceptable for all flight conditions encountered by the Regulus, are switched by relays actuated from airspeed and altitude information.

FIXES FOR REGULUS

A prime consideration in the design of the autopilot and stabilization system was to assure adequate stability and controllability of the Regulus throughout its flight path for all conditions it might encounter. Once the preliminary design was completed only a few significant difficulties arose, and these will be discussed here.

Control surface noise

A particularly noticeable condition was random movement of the ailavator control surfaces at their resonant frequency of about 30 cps. That is, random noise anywhere in the autopilot system made the ailavators oscillate at their resonant frequency. Investigation traced the source of the random noise to the electrohydraulic servo valve. Because of its configuration, the valve could not attenuate the high frequency noise without contributing excessive phase lag at the lower control frequencies. Therefore, the electrohydraulic servo valve was changed to a different type, one that exhibited desirable gain and phase characteristics. Noise in the 30 cps region was attenuated, eliminating the random movements of the ailavator surfaces.

When new, more stringent performance specifications for the Regulus were issued, they required an increase in computer gain to meet them. However, if the gains were raised, the random surface noise problem would reappear. Fortunately, Chance Vought designers were able to accomplish a narrow range of gain such that the computer gain could be high enough for adequate controllability and stability and low enough to eliminate surface noise.

Gyro noise

During initial prototype checkouts on the production autopilot system excessive noise appeared at the ailavator surfaces. Investigation indicated that the gyros were the noise source, the exact cause being a combination of structural feedback and engine air flow buffeting of the gyro platform. Several quick fixes failed to reduce the vibration to an acceptable limit.

The final solution was a bridged-tee filter, tuned to the resonant frequency of the structural feedback vibration, installed on the output computer. This fix proved very satisfactory, eliminating the structural feedback and the control surface noise. Further investigation showed that this problem could have been solved by physically relocating the gyros, but it proved less costly and more feasible to eliminate the noise by an electronic rather than a mechanical fix.

Turn tightening

The bank turn control system presented a serious problem in its initial design. Whenever bank turns were commanded above the coordinated airspeed with a turn rate greater than 60 deg per min, the missile would tighten up the turn. The wings' dihedral effect caused an increase in the bank angle and in an attempt to stop the lateral acceleration the larger bank angle increased the turn rate. Coupling between larger bank angle and the yaw gyro erection system caused more uncoordination.

Gyro coupling during the bank turn was studied and it was determined that this difficulty was due to the yaw gyro being precessed at a constant rate about the vertical axis of the missile. Modification of the yaw gyro's precession rate by a function of the bank angle proved to be an adequate solution. Here, when the precession rate is multiplied by the cosine of the bank angle, as the bank angle increases the precession rate will decrease. This fix maintains a constant turning rate in the horizontal plane and reduces almost entirely the tendency of the missile to tighten up the turn.

DATA FILE 46

Exact Solutions for Cubic and Quartic Equations

H. E. MERRITT, Flight Propulsion Div., General Electric Co.

In many engineering problems, and especially in control systems analysis, it becomes necessary to solve higher order equations. The general algebraic solutions of cubic and quartic equations are well known, but the procedures usually given are not explicit. This has resulted in the impression that use of formal procedures is a laborious task to be avoided. But the use of formulas generally leads directly to the roots with a minimum amount of time and labor compared to other methods. This Data File presents the required formulas and procedures concisely.

Formulas for the cubic equation

The general cubic equation is given by:

$$X^3 + bX^2 + cX + d = 0 \qquad (1)$$

The roots of this equation are,

$$X_1 = A + B - \frac{b}{3} \qquad (2)$$

$$X_{2,3} = -\left(\frac{A+B}{2} + \frac{b}{3}\right) \pm j\,\frac{\sqrt{3}}{2}\,(A - B) \qquad (3)$$

Where: $Q = \frac{d}{2} - \frac{bc}{6} + \frac{b^3}{27}$ $\quad P = \sqrt{Q^2 + \left(\frac{c}{3} - \frac{b^2}{9}\right)^3}$

$$A = \sqrt[3]{-Q + P} \qquad B = \sqrt[3]{-Q - P}$$

Procedure to solve the cubic equation: Compute Q, P, A, and B. The roots can then be found by the relations given in Equations 2 and 3.

Formulas for the quartic equation

The general quartic equation is given by:

$$X^4 + bX^3 + cX^2 + dX + e = 0 \qquad (4)$$

The roots of Equation 4 are the four roots of the following quadratics.

$$X^2 + \left(\frac{b}{2} + P\right)X + \left(\frac{R}{2} + PQ\right) = 0 \qquad (5)$$

$$X^2 + \left(\frac{b}{2} - P\right)X + \left(\frac{R}{2} - PQ\right) = 0 \qquad (6)$$

Where: $A = \frac{4ce - b^2e - d^2}{2} + \frac{c(bd - 4e)}{6} - \frac{c^3}{27}$

$$B = \sqrt{A^2 + \frac{\left(bd - 4e - \frac{c^2}{3}\right)^3}{27}}$$

$$R = \sqrt[3]{-A + B} + \sqrt[3]{-A - B} + \frac{c}{3}$$

$$P = \sqrt{\frac{b^2}{4} - c + R} \qquad Q = \frac{bR - 2d}{4P^2}$$

Procedure to solve the quartic equation: Compute A, B, R, P, and Q. The roots are then the four roots of the two quadratics given in Equations 5 and 6.

The formulas given are exact, and the values obtained for roots depend on the accuracy with which the operations are performed. The computations involved may be simplified by scaling of the roots in the equation to be solved.

The most complex operation which could be involved in using the formulas is the extraction of the cube root of a complex number. Let any number be expressed in polar form with a magnitude of A and an angle of α. Then by deMoivre's theorem the n values of the nth roots of the number are:

$$(A \angle \alpha)^{1/n} = A^{1/n} \angle [(\alpha + k\,360)/n]^\circ$$

where $k = 0, 1, 2, \ldots, n - 1$.

The root for $k = 0$ is called the principal root and is the one that *must* be used in the formulas given. Thus, the cube root of a complex number is the cube root of the magnitude and $\frac{1}{3}$ of the angle.

EXAMPLE OF A CUBIC SOLUTION

Given: $0.000001\,y^3 + 0.0003\,y^2 - 0.1\,y - 24 = 0$

Let $y = 100x$ to scale the roots and obtain coefficients convenient for manipulation in the formulas. Therefore

$$x^3 + 3x^2 - 10x - 24 = 0$$

Evaluating the formulas:

$$Q = \frac{-24}{2} + \frac{30}{6} + \frac{27}{27} = -6$$

$$P = \sqrt{(-6)^2 - \left(\frac{-10}{3} - \frac{9}{9}\right)^3} = j\,6.74$$

$$A = \sqrt[3]{6 + j\,6.74} = (9.02 \angle 48.3^\circ)^{1/3} = 2.08 \angle 16.1^\circ = 2 + j\,0.577$$

$$B = \sqrt[3]{6 - j\,6.74} = (9.02 \angle -48.3^\circ)^{1/3} = 2.08 \angle -16.1^\circ = 2 - j\,0.577$$

Therefore, the roots in x are:

$$x_1 = 4 - \frac{3}{3} = 3$$

$$x_{2,3} = -\left(\frac{4}{2} + \frac{3}{3}\right) \pm j\,\frac{\sqrt{3}}{2}\,(j\,1.15)$$

$$= -3 \pm 1 = -4 \text{ and } -2$$

Thus the factors in y are:

$$(y - 300)\,(y + 200)\,(y + 400) = 0$$

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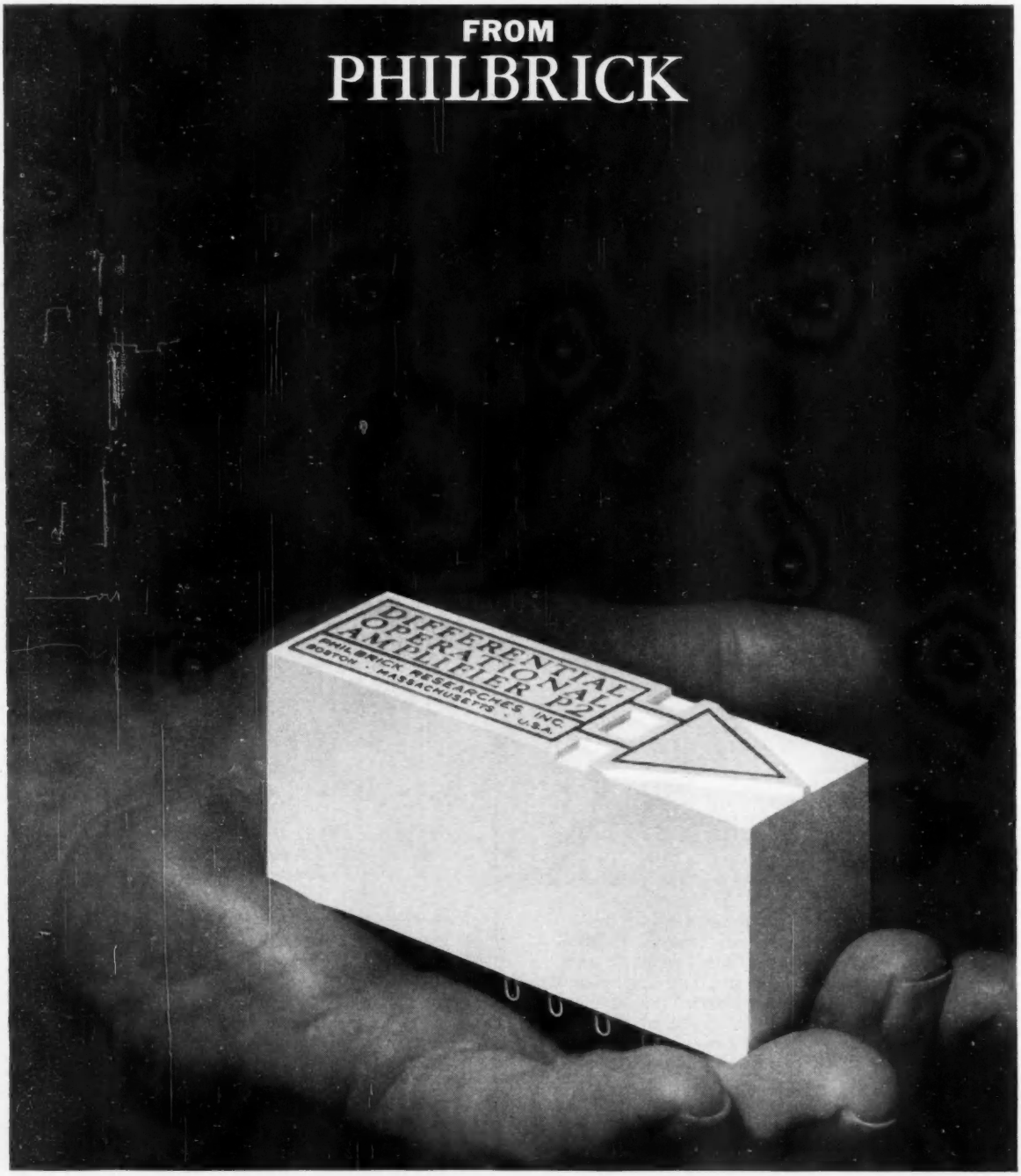

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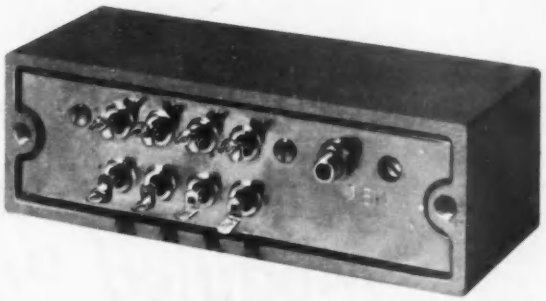


THE P2 IS UNIQUE — It is very likely that here — inside this rugged 4″ cast aluminum housing — is packed more performance and more versatility than you will find in any operational amplifier available in the world today.

A strong statement. One we're happy to back up with facts.

THESE ARE ITS FEATURES: Full differential input (truly floating with respect to ground). **Low input current** (typically less than 2×10^{-11} amp). **Low noise** (typically under 10 microvolts in the frequency range between DC and 1 KC). **Long term drift stability in sub-millivolt region. Coolness** (about 330 milliwatt dissipation). **Compactness** (4″ L x 1¼″ W x 1 11/16″ H; weight 11 oz.). **Economical operation** (no heater supply or tube replacement.) **Low price: $210**

HERE'S WHAT THE P2 CAN DO

The P2 is a dc amplifier with differential inputs, designed for analog computation and other instrument applications. These run all the way from high reliability process control to biological measurements. You can add, integrate, scale, and invert with it. Its differential inputs permit high impedance voltage following and amplification, subtraction, precise current driving to grounded loads, and many other esoteric and desirable operations.

Since inputs are electrically isolated from ground, there is no limit on the input common mode signal, except for the dielectric strength of the insulating materials. In addition, the P2's high input impedance and low input leakage accommodate the same resistors and capacitors normally used in vacuum tube circuitry: but with lower voltage ratings, greater compactness, and longer life.

Typical drift, when connected as a ten-second integrator using a one microfarad capacitor, is typically less than 100 microvolts per second.

The P2 requires 11 ma at plus and minus 15 volts from conventional supplies. Where portability is desired, it will operate continuously for about 75 hours in the field on just two pairs of small mercury batteries (TR-136 type).

SPECIFICATIONS

(Tentative)

ELECTRICAL

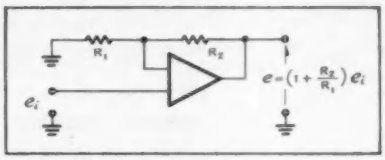
	Design	Q.C. pass limit
Gain:	30,000	20,000
Output range:	± 11V at 1.1 ma	± 10.0 volts at 1.0 ma
Minimum recommended load resistance:	10 KΩ. Will not be damaged by short circuit. Resistance loads below 10 KΩ tend to degrade the amplifier performance, but are feasible from the standpoint of safety.	
Input:		
Tolerable common mode signal level range:		± 200 volts
Admittance:	600 μμf	
Current: (at room temperature)	2×10^{-11} amp	10^{-10} amp
Drift: (referred to inputs) (20°-45°C.)	2 mv	5 mv
	typically less than 100μV in 8 hours at constant temperature	
Bandpass:	Small signal — unity open-loop gain at 75 kc	
	Large signal — output becomes amplitude limited at 1 kc	
	Output range will be reduced by 12 db/octave above 1 kc	
Power requirements:	± 15vdc at less than 11 ma (worst case load)	

MECHANICAL

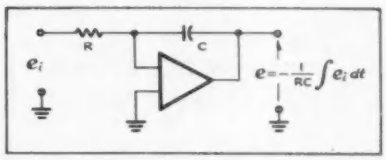
Dimensions:	4″ L x 1¼″ W x 1 11/16″ H plus ⅜″ additional clearance for terminals
Mounting:	3 11/16″ centers, 2 holes for No. 8 screws (furnished with unit)
Weight:	Mounted: 11 oz. Packed: 1 lb.
Enclosure:	Potted, cast aluminum case

For aid with your applications and for a demonstration of P2's capabilities, write, wire or phone Philbrick or your nearest Philbrick representative.

Ideal for computing instruments like these

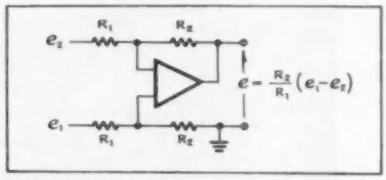


ELECTROMETER (ISOLATION) AMPLIFIER (non-inverting application): This circuit presents an extremely high dc input impedance to the source (actually higher than that of a K2-W amplifier by several decades). The gain ratio is determined by the feedback elements and is positive in polarity. Applications of this circuit include potentiometer unloading, peak-reading instrumentation, preamplification, and portable low-level electrometer-type measurements.



INTEGRATOR-MEMORY: P2's low input current and drift allow one to use high impedance values for R and C not usually considered feasible for transistor amplifiers. Considerable saving in the cost and bulk of polystyrene capacitors is inherent.

Example: R = 10 Megs and C = 1 μf gives a 10 second integration circuit.
Less than 30 millivolts error in the output is typical for a 5 minute period.



DIFFERENTIAL AMPLIFIER: The common mode rejection of this circuit is high indeed, being determined by the accuracy with which feedback ratios are maintained. Because of the input isolation, hundreds of volts of common mode signal are feasible without causing damage. The dc load on the source is almost entirely caused by the resistors alone. Using this circuit in conjunction with two pre-amplifiers of the type shown in Fig. 1, a precision differential electrometer is feasible.

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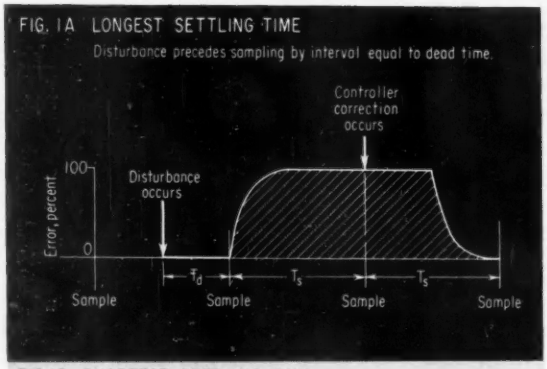
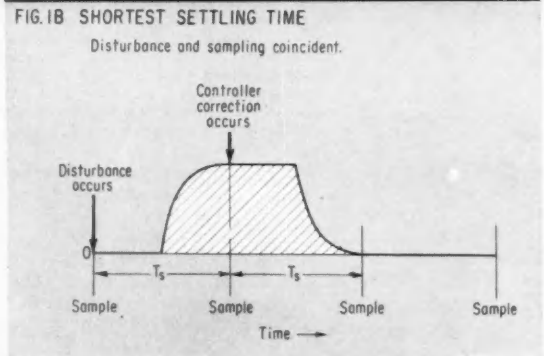
Get the Benefits of Sampled Data Control from Modified Process Controllers

THE GIST: Contrary to intuition, sampling control receiving intermittent process data can often be superior to conventional continuous control. In particular, a process dominated by dead time—a common situation in many operating plants—is difficult to control with continuous controllers. However, a properly designed, properly adjusted sampling controller can assure fast, stable recovery from a process disturbance.

The author first demonstrates sampling control graphically for a typical dead time process, and then describes the modification, operation, and tuning of a sampling controller devised from a conventional pneumatic process controller.

MORTON J. HAUSNER,
Fischer & Porter Co.





As an example of a process dominated by dead time (or transport delay), consider a process containing a dead time T_d of 12 min and a single lag time constant T_1 of 3 min. That the process is dead-time-dominated is a clue to the possible beneficial use of sampling control over continuous control.

Frequency response analysis of this process shows that for minimum recovery time following a disturbance the settings for a continuous controller should be a proportional gain of 1.1/process gain and a reset time of 30 min, the longest reset time available on most commercial controllers. Here, rate action will be relatively useless. These settings permit the process to recover with a decreasing-amplitude oscillation (¼-amplitude decay ratio) having a period equal to the reset time. Assuming three cycles are required to return to equilibrium, the total settling time will be 90 min. Thus longer dead times will require unattainable reset times.

Sampling control recovery

Next, consider settling time following corrective action as calculated in the time domain. Here, the settling time is that required to attain 98-percent response completion to a step change in input. For a single-order time constant, settling time equals four time constants. Thus for the stated example, the total settling time is the dead time plus four time constants, or $12 + 4\ (3) = 24$ min. The total settling time determines the sampling interval T_s for the sampling controller.

What the sampling controller does is outlined in the box. For the given case, the controller would momentarily sense the error in the controlled vari-

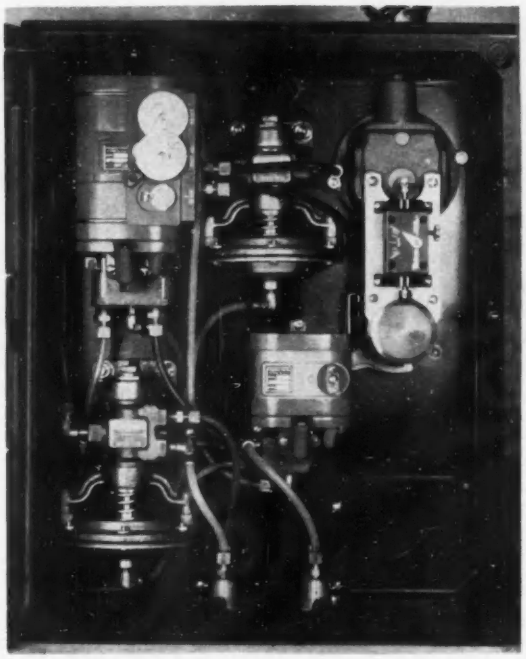


FIG. 2. Prototype pneumatic sampling controller for field trials.

able every 24 min and make correction in the manipulated variable proportional to the error.

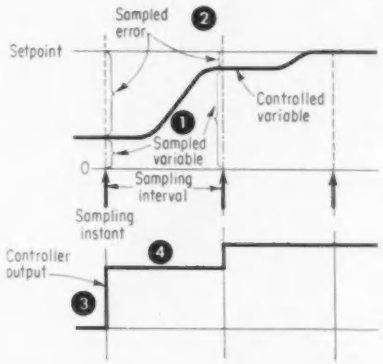
However, the actual settling time to equilibrium for the optimally set sampling controller depends on when during the sampling interval the disturbance occurs. Figure 1A shows that the longest settling time arises when the disturbance occurs at a time equal to the dead time prior to the sampling instant. In addition the control system requires one full sampling interval for the disturbance to reach equilibrium and be sampled again and another full period for the manipulated-variable step change to act through the process dead time and time constant and restore the controlled variable to zero error. Thus the longest settling time is $2T_s + T_d = 48 + 12 = 60$ min. By similar analysis, Figure 1B shows the shortest settling time occurs when the disturbance is coincident with the sampling instant. The shortest settling time equals two sampling periods, or 48 min. Obviously, even the longest settling time of 60 min for the sampling controller is less than the 90 min for the continuous controller, so sampling control gives considerable advantage.

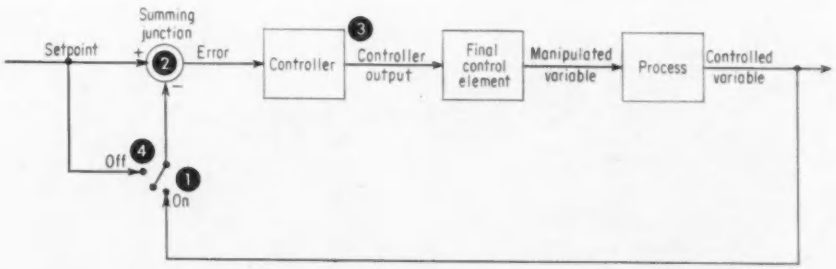
Sampling control hardware

Because sampling control can offer significant benefit in controlling dead time processes, a simple pneumatic sampling controller has been devised and built for field trials. The sampling controller, Figure 2, is essentially a modification of the conven-

SAMPLING PNEUMATIC PROCESS CONTROLLER

1 Samples controlled variable at equally spaced instants.
2 Compares measured value with setpoint value during sampling interval, thus deriving a sampled error.
3 During the sampling instant, changes its output to correct error by changing the manipulated variable.
4 Clamps new controller output until next sampling instant, inserting setpoint at both inputs to summing junction.





tional continuous proportional plus reset pneumatic controller. The operation is shown in Figure 3.

A variable speed drive rotates a split cam arrangement, permitting sampling periods up to one hour. The split cam actuates the *ON-OFF* controller to periodically switch the sampling controller from a clamped or *OFF* mode to an active or *ON* mode. The *ON* time is about 1 percent of the *OFF* time. The 3 or 15 psi output pressures from the *ON-OFF* controller switch the two-way and three-way pneumatic valves. Note that the passage between controller output and the reset chamber is brought out and is plugged or unplugged by the two-way valve.

In the *ON* mode, the sampling controller behaves as a conventional proportional plus reset controller. In the *OFF* mode the setpoint pressure is now fed to the setpoint port and the measured variable port. The pressure in the reset chamber—which at the end of the *ON* time is proportional to the required correction—is locked in and becomes the clamped output of the sampling controller.

Figure 4 demonstrates how the sampling controller changes output during the sampling instant or *ON* time. Assuming the controlled variable is not at setpoint when the controller switches to *ON*, an immediate proportional correction occurs followed by a ramp correction due to reset action. At the end of the short *ON* time, the switched input port rearrangement causes subtraction of the original proportional correction. Thus, the net incremental change in controller output is that due to the final value of the reset correction and equals:

$$\text{proportional band} \times \frac{\text{ON time}}{\text{reset time}}$$

The magnitude of the net change is easily adjusted by varying the proportional band and the reset time. For a given sampling interval, the *ON* time is fixed. Generally speaking, it would be advisable to use a wide proportional band and small reset time.

The net incremental change in controller output may be viewed as being related to sampling controller gain and is selected such that its value is consistent with the over-all process gain. That is, if for continuous control a 5 deg F temperature error requires a 1 psi change in controller output, then for a sampling controller seeing the same temperature error the same 1 psi output change can be predetermined by calculation of judicious values of proportional band and reset time. Final adjustment of settings will probably be required after the sampling controller is installed and operating in the plant.

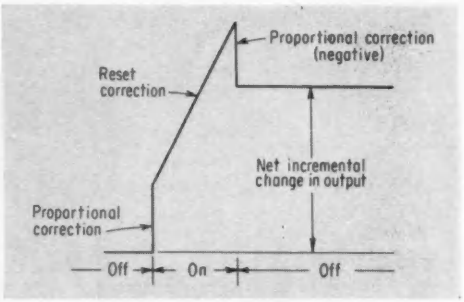
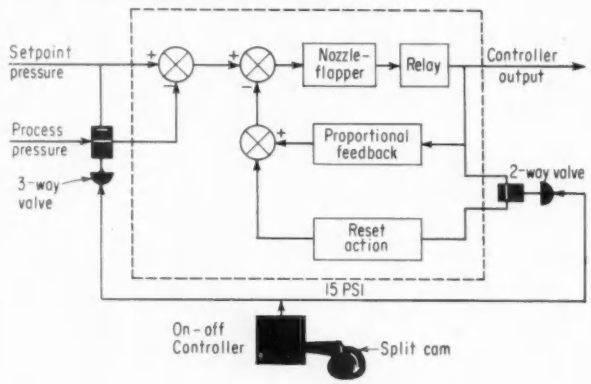
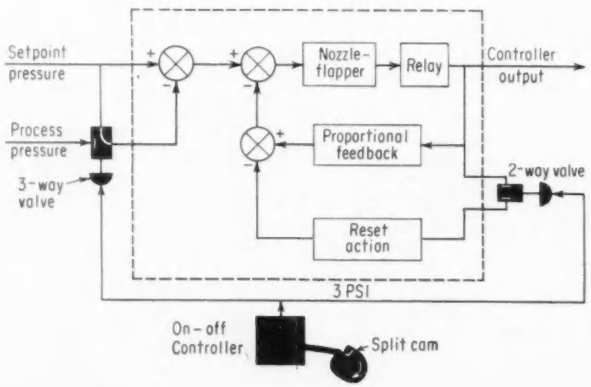


FIG. 4. Sampling controller output, clamped during OFF mode, depends on settings of proportional band and reset time.

FIG. 3. How sampling controller switches to ON and OFF control modes.





Sampling control applications

Typical potential applications for the sampling control are in such dead-time-dominated processes as:

Control of column overhead product using a stream analyzer and reflux control. In many cases the analyzer, itself a sampling system with a finite holdup time, adds dead time to the control loop.

Basis weight control on a paper machine. Here, the basis weight measuring means may be separated from the final control element by the entire length of the machine, resulting in a process characterized by almost pure transport delay.

Chemical treatment of water and waste where a combination of transport time and residence time is necessary before the final results of treatment can be measured.

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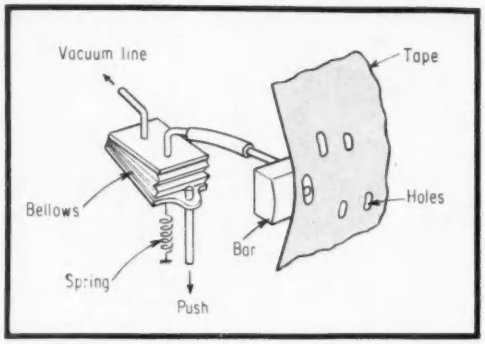
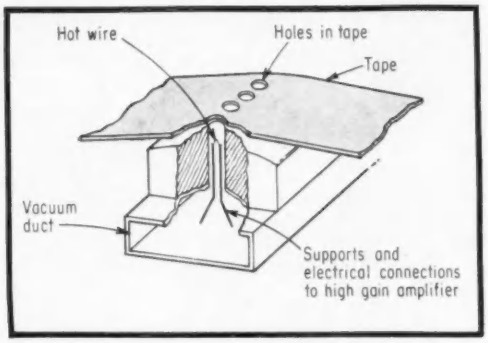
Eight Ways to Read Punched Tape

PAUL RUTTKAY, Burroughs Corp.

AIR SENSING

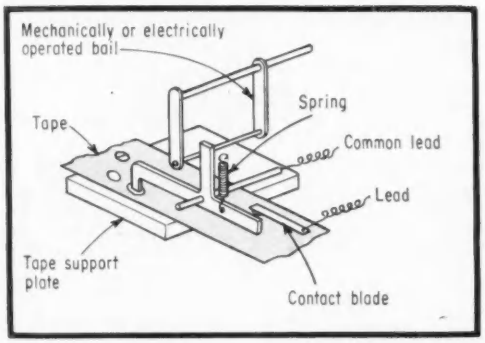


1. An old method of reading punched tape pneumatically, used widely in the player piano. Tapes are wide, of coarse pitch. The technique is simple, rugged, not very fast. When a hole in the tape opens the port in the metal bar, atmospheric pressure allows the spring to expand the bellows to give a direct mechanical push.

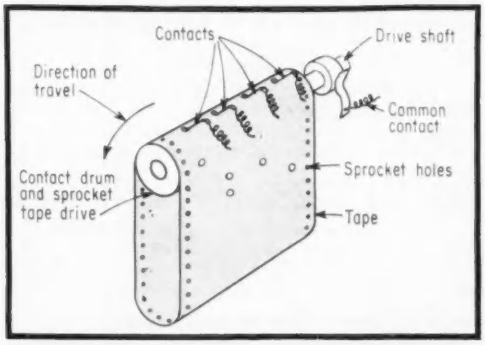


2. The hot wire anemometer technique is the newest way being used to read punched tape. A small wire, about 0.0005 in. diam by about $\frac{1}{8}$ in. long, is supported in a duct and heated by current. When hole in tape opens, air flow changes wire temperature, hence resistance, providing a low-level electrical signal. Capable of very high reading rates.

MECHANICAL FINGERS



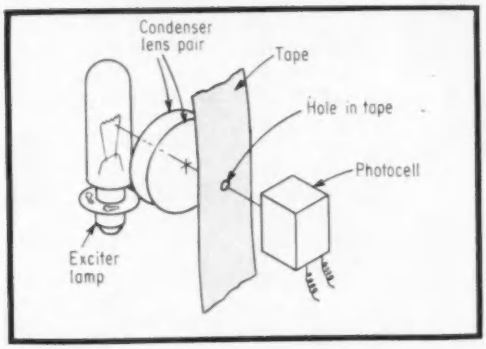
3. A conventional method of reading stepped tape. The tape is supported by a block with a hole for for each channel. While the tape is in motion, bail holds contact levers up. When tape stops, fingers rest on tape. Where there is a hole, finger enters it, making the electrical contact. This design has many variations, such as offset fingers for more contact room, double-contact blades for isolated channels, etc. Contact blade spring period can be critical. Cost moderate. Speed about 5 pitches per sec. Tape about 1 in. wide, 8 channels plus sprocket on $\frac{1}{10}$-in. centers; other sizes can be used.



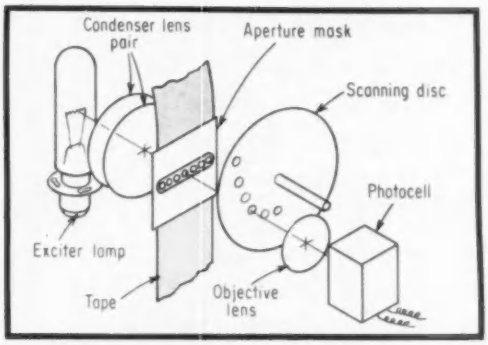
4. A conventional method of reading program tape. Tape can travel one direction only—reversal will damage contacts. A wide variety of contacts readily available from stock. Maximum speeds with stepped tape motion about 40 steps per sec; with continuous tape motion, as high as 60 in. per sec. Contact life several million cycles. As many as 50 channels can be placed on a 3-in. wide tape, each channel controlling one circuit. Sprocket pitch about $\frac{1}{10}$ in. Although contacts can operate small current relays, electronic equipment may be better. Mechanical cost moderate, electronic cost can vary.

Here are eight basic techniques now in use to read the digital information from punched paper or plastic tapes. Three different mediums are used to sense a hole in the tape: air, mechanical fingers, and light. Only the method of producing an output signal that represents the presence of a hole is shown—design details of complete reading stations or additional electronics that may be necessary have been omitted.

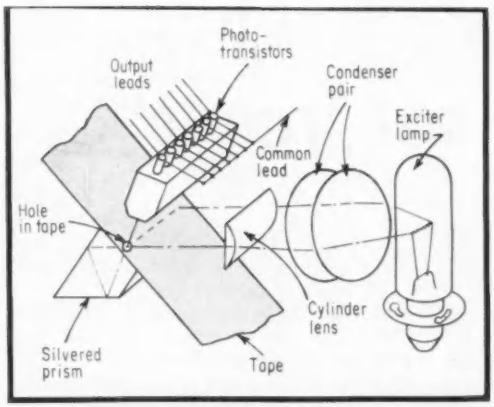
LIGHT SENSING



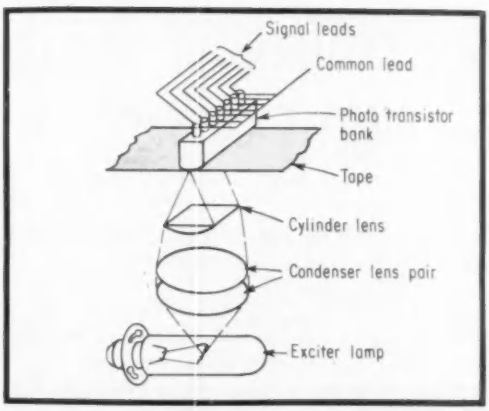
5. The basic technique for reading punched tape photoelectrically. Fast, reliable, quiet, with no moving parts. May be used with stepped or continuously moving tape. Uses one photoelectric cell or photomultiplier tube for each channel. Prisms, mirrors, light pipes, lenses, etc., used to spread light beams from channels to obtain room for photocells. Cost intermediate.



6. Photoelectric system using one photocell and a mechanically driven scanning disc to give a serial output from the tape. The scanning disc replaces electronic equipment otherwise required to obtain serial output for single line transmission of the tape information.



7. A silvered prism behind the punched tape reflects light from the exciter lamp back out through the same hole, to fall normally on the phototransistors. This same arrangement will also read opaque tape with printed dots by reflected light (the prism being inoperative). Approximately the same ranges and limitations on reading speeds and channel spacing as in the more common arrangement in Figure 8.



8. An optional method for high-speed reading of 6, 7, or 8 channels (plus sprocket) using small phototransistors (about 0.080 in. diam by $\frac{5}{16}$ in. long) mounted in phenolic block directly over the center of the $\frac{1}{10}$-in. spaced information channels. Reading speeds from about 7 to 1,000 characters per sec, depending on tape drive mechanism. (Present phototransistors have a maximum limit of about 10 kc). Cost relatively expensive.

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A Design Approach to Communication Links for Space Vehicles

THE GIST: Radio telemetry has been used for collecting data in aircraft and missile flight test programs for years and has lately become the communications link for satellites and space vehicles. Telemetry designs for the space vehicles of the future will have to operate over greater distances for longer periods of time with wider transmission bandwidths than those used so far. And these systems must satisfy these increasingly difficult requirements in the stringent environmental conditions of the space vehicle. This article presents a proved procedure for designing space telemetry systems, illustrated by application of the procedure to a typical system for a near space probe.

FRED SINNOTT, Convair Astronautics

The major guides for any system design must always remain unchanged: successful completion of the system's purpose at the lowest over-all cost possible. In the case of the space vehicle telemetry system, these major design guides are the same as for any missile or satellite-borne telemetry system:

• *Analysis of measurements.* The measurement requirements should be known as completely as possible at the outset of any telemetry system design, but usually the designers of the other vehicle subsystems are also only beginning their designs and they may have a poor idea of their exact measurement requirements for analysis.

• *Flight profiles and missions.* The system design must consider the mission and flight profile to establish limiting conditions of range and visibility of receiving stations to permit maximum data transfer during powered flight and in orbit. Maximum use should be made of existing ground receiving stations. Figure 4 shows many of the existing receiving stations around the world, plus an arbitrary trajectory which could be the first portion of a deep space probe or of a stationary Earth satellite. Selection of world-wide receiving sites becomes less important as the vehicle gets farther and farther from Earth since the stations with the largest antennas and maximum gains must be used and horizon limiting is not important.

• *Budgets and firing schedules.* Economics and the scheduled completion date often dictate that a long proved technique be used as the basis of system design, even though it is obvious that a little used technique would give somewhat better performance. The reasons are increased development costs, forced obsolescence of present equipment, and the chance of delaying the scheduled firing date.

• *Environments.* Like the measurement requirements, these should properly be an input to the design problem, but are likely to vary from those predicted at first when the program moves along. Subsystem designers must usually start by assuming more severe conditions than those that will actually prevail.

• *Special requirements.* Lumped here with the easily-asked-for maximum reliability and minimum size and weight are such requirements as extra-long operating times and special packaging limitations, such as the shape of the telemetry package.

Space flights compound operating problems

Radio telemetry systems for space vehicles are differentiated from those for missiles and low altitude satellites by a number of more difficult operational requirements. The greater distance over which data must be transmitted is the most significant difference since it makes important certain considerations which are secondary at short ranges, such as bandwidth, antenna gain, and type of modulation. Table I indicates what happens to radio power requirements as interplanetary distances increase, other transmitter, receiver, and receiving antenna characteristics being constant. As shown, compromises must be made in many of these system characteristics or outlandish power is required even within the near

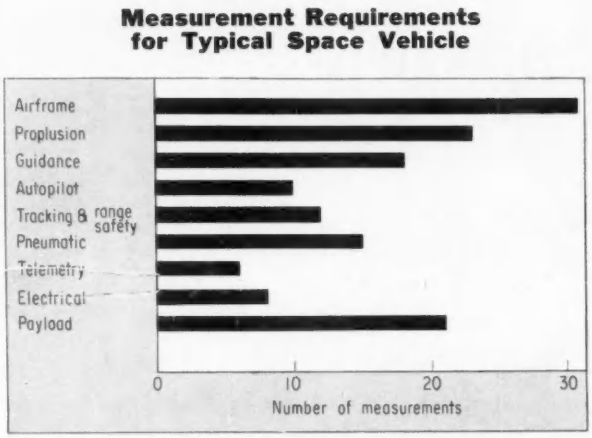

FIG. 1. Plot of 144 measurements to be telemetered from a typical space vehicle by subsystem. These requirements must be expected to change as subsystems are further developed, and from mission to mission.

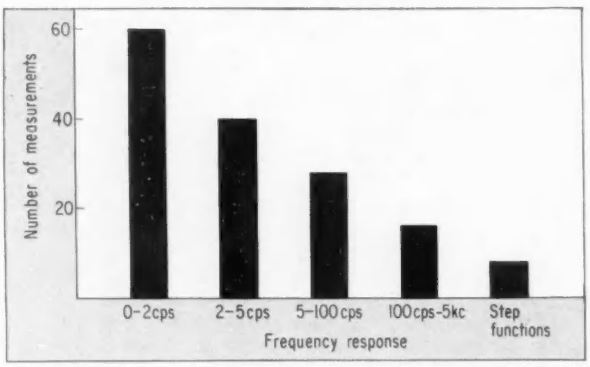

FIG. 2. Number of measurements telemetered grouped by maximum frequency response in measurement.

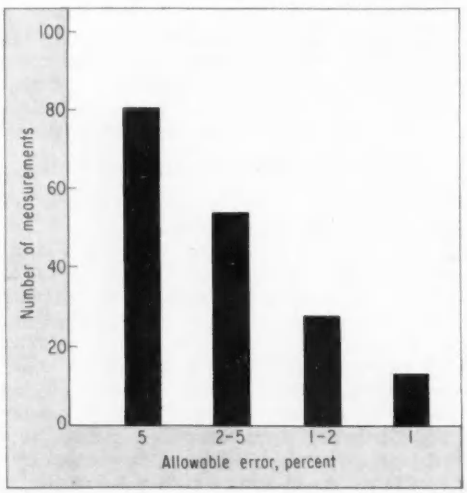

FIG. 3. Number of measurements grouped by maximum allowable error.

solar system, and telemetry over interstellar distances would seem practically impossible.

A second important factor is the generally greater number of measurements to be telemetered from space vehicles, which will usually make many scientific measurements enroute and at their destinations as well as report on vehicle performance. This increasing amount of data will require increasing transmitter bandwidths, making signal to noise problems more difficult.

The total time period during which the telemetry system must operate to provide measurement data will also increase as mission distances increase and techniques of initiating transmission only at timed intervals or upon command from Earth will have to be used to conserve power.

Certain environmental conditions, particularly temperature extremes, may also become more severe. For example, temperatures on the moon can vary from minus 100 deg C at night to plus 150 deg C during the day, and a requirement that a transmitter be able to operate at any time can present a very difficult design problem.

Increasingly difficult requirements such as these, together with other factors which may be peculiar to specific missions, mean that the design of a space vehicle telemetry system is not a cut and dried procedure, and many of the design rules presently followed have to be modified. The general approach must be to consider all of the factors that will affect the design and to give each its proper weight to find the best solution.

A system design procedure

Telemetry system design procedures vary principally in which parameters the designer fixes first, and this choice is largely determined for him by the relative importance of the requirements for the specific mission and vehicle. Therefore, an example will be used to illustrate an approach that has been used successfully on several space programs as well as on ballistic missiles. The typical design problem is stated in the box (opposite) with an outline of the design procedure suggested.

Taking the steps one at a time for the problem described:

1. A large number of modulation combinations exist, with various technical advantages and disadvantages. Fortunately, there has been considerable theoretical work on comparison of signal to noise ratios, detection thresholds, information efficiency, etc. Figures 5 and 6 show that there are significant differences in such factors for different modulation techniques.

The choice of a modulation technique depends on the kind of measurements to be made, the data reduction equipment available, the characteristics of available in-flight equipment, as well as real engineering experience. The distribution of the measurements in Figures 1, 2 and 3 directed the use of a modulation scheme which could handle a large number of low frequency response measurements and a few high frequency response measurements (up to 5 kc). A close check on the 5 kc measurements showed that very little amplitude accuracy would be required of the modulator since

the measurements would be coded into digital form prior to transmission. In fact, the accuracy requirements were relatively low on most measurements (see Figure 3). There were also some step function or time of occurrence measurements. Measurement changes were anticipated because it was still early in the development program, so flexibility had to be built in.

Based on the measurement requirements FM/FM was chosen as the modulation scheme. The low frequency response measurements could be commutated (PAM/FM/FM) to conserve bandwidth and the higher subcarrier channels used to handle the higher frequency measurements, including the digital data. Flexibility was provided by unused commutator segments and extra subcarrier

A SYSTEM DESIGN PROCEDURE

A typical problem

Design the telemetry system for an upper stage vehicle capable of placing a large payload in a 24 hour orbit at 20,000 miles altitude or a lesser payload on the moon or a near planet. The vehicle will be placed in a low altitude parking orbit and re-ignited at optimum points in the orbit to maximize payload. The telemetry system must provide vehicle performance and payload data during both powered and coasting portions of flight. Additional stages may be required for certain missions, so the telemetry system design must be flexible. The data given by Figures 1 through 4 are design inputs for this problem.

The design procedure

1. Choose a modulation technique.
   This choice fixes the design of many other portions of both the vehicle and ground equipment and is the logical parameter to fix first in a telemetry system design.
2. Specify design of radio transmission links.
   Carrier frequency, rf bandwidth, and transmitter power can be determined once the modulation technique is fixed.
3. Determine signal conditioning requirements.
   Choose circuits and components to transform measurement formats for input to modulation system.
4. Design power control and programming systems.
   Various command control and programming techniques for conserving power supplies should be considered at this point.
5. Design telemetry packaging.
   With main system components selected, the packaging problem can be attacked.
6. Finally, consider special techniques.
   The possibilities of improving system design with special techniques for combining functions, controlling bandwidth, and sharing power sources, for example, should be considered last to determine their effect on system weight, reliability, etc.

TABLE I

POWER REQUIRED FOR INTERPLANETARY TRANSMISSIONS

Destination	Power required
Moon	39 watts
Venus	39.8 kw
Mars	1 Mw
Sun	5 Mw
Jupiter	100 Mw

Assumptions

250 ft ground receiving antenna
0 db gain vehicle antenna
10 db receiver margin required
7 db safety factor
250 Mc carrier frequency
100 kc receiver if bandwidth

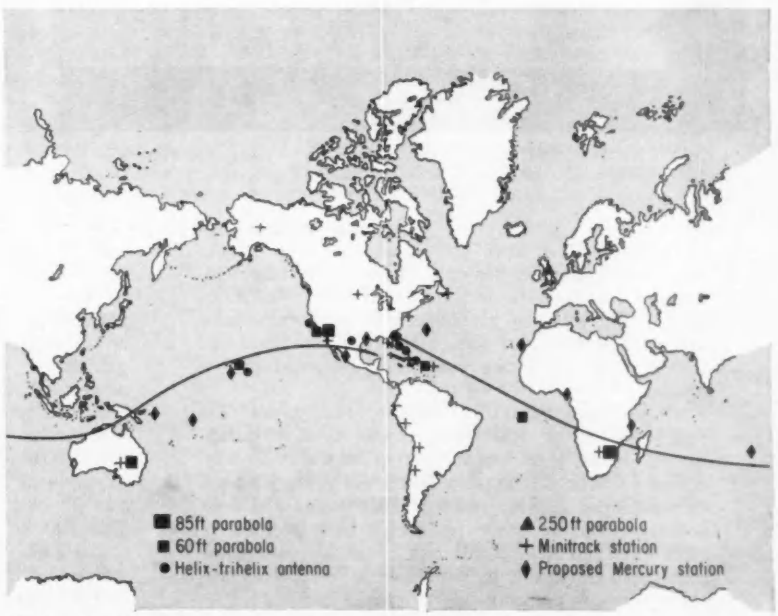

FIG. 4. World-wide ground receiving networks, including location of large parabolic antennas for deep space reception.

Comparing Modulation Techniques

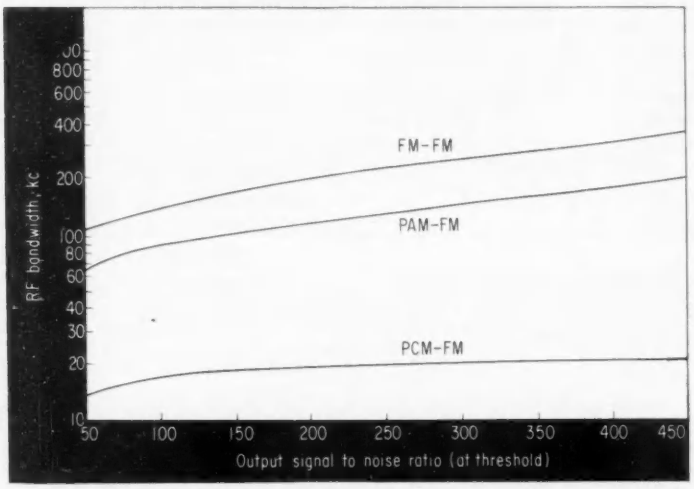

FIG. 5 Required rf bandwidth vs minimum allowable output signal-to-noise ratio at threshold for several modulation techniques.

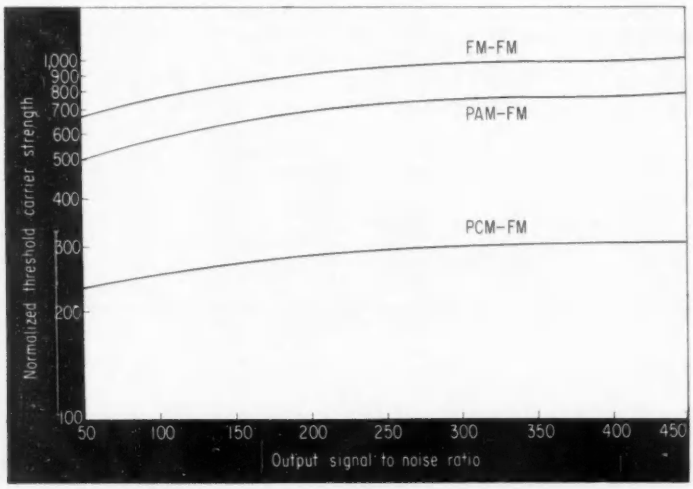

FIG. 6. Threshold signal carrier strength vs minimum allowable signal-to-noise ratio for several modulation schemes.

channels. Most step functions could be superimposed on continuous data channels without significant loss in data or time definition. The choice of FM/FM was also strengthened by the existence of FM/FM test and data reduction facilities and the experience of the engineers assigned to the project.

2. Once the modulation scheme was chosen the radio frequency link design was readily established. First, the rf carrier frequency was chosen. Although future telemetry frequencies are planned in the 1,400-1,500 Mc and 2,200 Mc bands and even actually used in some places, it was decided to stick with the 230-260 Mc band, which would allow maximum coverage by world-wide receiving stations for low parking orbits (see Figure 4).

Knowing the rf carrier frequency and the signal to noise ratio required at the receiver output, it was mainly a mechanical chore to compute the vehicle transmitter power required. The calculations of Table II assumed a maximum range of 22,000 miles and a standard RDB telemetry system 500 kc if receiver bandwidth).

No fixed rule exists for the amount of a safety margin and figures from 7 db to 20 db are used. A nominal power output of 50 watts was decided upon for this application. No attempt was made to overpower radio noise (17 db) from the sun even during quiet periods. This noise would only be a problem when the ground antenna is looking directly at the sun and it was not feasible to design for this condition at the expense of added weight. The transmitter antenna gain was assumed to be 0 db. Higher gain vehicle antennas are certainly desirable wherever possible, but it was felt that the requirement for isotropic coverage outweighed the disadvantage of additional airborne power and weight since the telemetry system had to provide data in cases of attitude control failure.

3. A careful analysis of the measurement devices established the basic requirements of the signal conditioning circuitry. Standard design techniques were used to provide amplifiers, demodulators, discriminators, transducer power supplies, and similar equipment. Some special techniques for signal conditioning are considered under step 6, such as bandwidth conversion.

4. Usually ground power is used until take-off, after which batteries aboard the vehicle furnish the required power. On some missions the space vehicle telemetry system may not be turned on until the vehicle is out in space. Generally, very little telemetered data is required during long coast periods in the vicinity of the Earth or during interplanetary travel. Hence, the telemetry system is turned on and off as required by internal programming or by ground command to conserve power. It is also possible to program the bandwidth to make the power radiated compatible with measurement requirements at all times in the flight. Bandwidth control was achieved in our example by using two telemetry systems—one at 100 kc bandwidth and one at 500 kc bandwidth. The 100 kc system radiates 10 watts and is on continuously, while the 500 kc system radiates 50 watts and is programmed on internally as needed.

5. Packaging techniques in space vehicle telemetry

are essentially the same as for missile applications with several exceptions. First, the equipment may not have to operate during periods of extreme vibration, but must only survive such vibration for later operation. Second, requirements for prolonged operation in a vacuum with solar radiation and no massive heat sink for mounting dictate a packing arrangement where components may be mounted at the top of a package rather than the bottom (or the package turned over), with fins and special surface treatments utilized to maximize heat transfer out and minimize heat transfer into the package. Other packages which may be inoperative for long coast phases of the trajectories must be designed to minimize heat transfer out of the packages.

It is also important to provide a packaging arrangement such that decreased measurements can decrease space and weight. As a particular flight test program continues the number of telemetry measurements usually decreases and some of the space and weight originally utilized for telemetry must be relinquished for payload usage.

6. There are several aspects of the system design for this particular application that require special attention. These are areas where significant and unique system improvements are possible:

a. Combination telemetry and tracking. The combination of the vehicle telemetry and tracking transmitters reduces weight and power requirements. This scheme has already been used with notable success on many current space vehicles but the bandwidth of the telemetry data has been severely restricted on those programs. In the design of the space vehicle telemetry system outlined in the previous sections it was decided to use tracking transmitters as a supplement to the regular telemetry systems (500 kc and 100 kc). Limited telemetry was added to these transmitters at a minimum increase in weight and power since the transmitters were already aboard for acquisition and tracking. These transmitters, modulated by low frequency subcarrier oscillators, permit telemetry of certain environmental parameters during coast periods or after final burnout when the wide band telemetry systems are not operating.

b. Bandwidth conversion. Since transmitter power and weight are directly proportional to bandwidth, the reduction of this bandwidth without compromising measurements is significant. Bandwidth reduction techniques must be used carefully since the added system complexity reduces the reliability of the measurement.

A special technique for conservation of bandwidth was used for the space vehicle whose measurements are listed in Figure 2. The step function measurements required very accurate time definition. Application of conventional FM/FM telemetry techniques would require use of the higher frequency subcarrier oscillators to provide satisfactory time resolution. From the nature and frequency response requirements of the measurements at least three of the higher subcarrier channels would have been required and this was incompatible with the over-all bandwidth limitations. The problem was resolved through the use of triple FM with 10 low frequency oscillators turned on and off by the functions to be monitored. These low frequency oscillators in turn modulated a channel 10 subcarrier which was the lowest channel with adequate frequency response. Data reduction of this data is accomplished through appropriate filters at the output of the channel 10 discriminator.

TABLE II

CALCULATION OF VEHICLE TRANSMITTER POWER

Assumptions	
Carrier frequency	230 Mc
Receiver bandwidth	500 kc
Receiver improvement threshold	10 db
Receiver noise figure (NF)	5 db
Calculations	
1. Receiver noise level	−147 dbw
2. Receiver required S/N input	+ 15 db
3. Receiver sensitivity	−132 dbw
4. Receiver antenna gain (TLM-18)	− 30 db
5. Level required at receiver antenna input	−162 db
6. Path loss 22,000 statute miles	+171 db
7. Required radiated power	9 dbw
8. Transmitter antenna gain	0 db
9. Transmitter antenna power required	+ 9 dbw
10. Required transmitter antenna power	7.94 watts (+9 dbw)

c. Dual use of power sources. It has been customary to power telemetry from its own power source to prevent data loss due to failure of main power supply. In this case the telemetry system was powered by the main power source under all usual conditions, but an emergency power source was provided with 5 min of energy for the telemetry system. This secondary power source is utilized to energize the minimum power tracking transmitters at the end of a normal flight. Thus, the extra weight utilized by this separate power source is never wasted.

Improvement for the future

Future telemetry systems can be improved most by developments in:

- Higher gain vehicle antennas. High gain vehicle antennas are presently little used, but with improved attitude control of space vehicles large parabolic dishes become a good possibility for improving system performance.
- Further sharing of command, tracking, and telemetry functions on a common rf link.
- More sophisticated use of variable bandwidth and power techniques to maximize efficiency of data transmission.
- Combination of several modulation techniques into one system having some of the advantages of each modulation scheme.

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Electrolytic Tank Simulator Plots Fields Automatically

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Feedback Controls, Inc., subsidiary of New York Airbrakes Co.

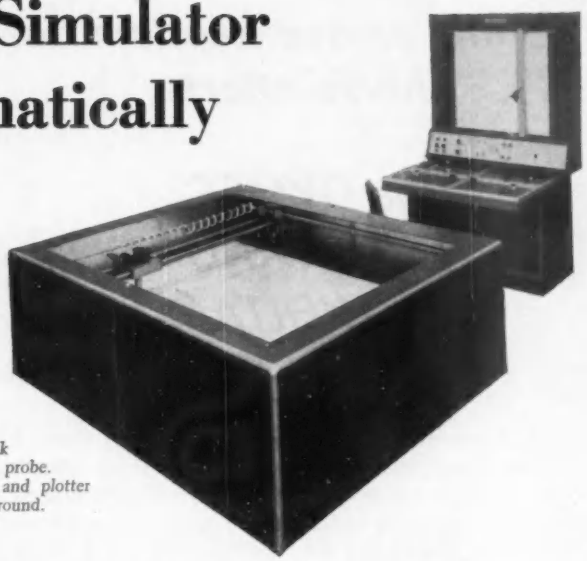

FIG. 1. The tank and servo-driven probe. Control console and plotter are in the background.

A new field analyzer built by Feedback Controls, Inc., automatically charts the electric field in a two-dimensional electrolytic tank on a standard X-Y plotter. The analyzer was designed for Sinclair Research Laboratories, Inc., for use in studying secondary oil extraction, the method of recovering oil in which water is pumped into certain wells to displace oil which is then pumped out of other wells. With ordinary electrolytic tank simulators, often used to investigate electric and magnetic fields and liquid and heat transfer, an operator manually positions a probe to detect the voltage and field direction at each point in the tank. The FCI device tracks the streamlines and equipotentials, indicates the positions of wavefronts, and measures the area inside closed curves. The probe can be replaced with a router and used for shaping the bottom of the tank to stimulate a nonuniform medium—variable earth permeability in the oil field case.

The system (Figure 1) consists of a tank unit, control console, conventional X-Y plotter, and optional current amplifier assembly. The tank is a hollowed out Styrofoam block filled with electrolyte and set inside a 73 x 84 in. desk height frame. The probe (Figure 2) has five vertical wires protruding from a horizontal plate into the electrolyte. Slip rings on the probe shaft bring out the voltages on the wires. A small damper-stabilized servo rotates the plate about a vertical axis through the center of the wire formation, and a resolver is geared to turn with the probe.

This assembly slides in the Y direction along two parallel horizontal guide rods. The Y servo assembly is mounted on one of two end blocks that hold these rods. The servo turns a tachometer-generator, a precision potentiometer for deriving a dc voltage for the plotter, and an output capstan. The capstan drives a length of aircraft cable that moves the probe in the Y direction through a travel of 48 in. Both blocks holding the Y-direction rods slide in the X direction on two guide rods fixed to the frame.

The entire assembly which moves in the X direction is called the carriage and is driven through a travel of 60 in. by another servo (with tachometer) coupled by a cable to one of the end blocks. A parallel servo operating from the same power amplifier drives the opposite end block to prevent carriage twisting or cocking. The maximum speed of the probe in either direction is about 2 ips, and the linearity of velocity with respect to input signal is about ±0.5 percent.

Figure 3 shows the field analyzer operation when tracking steamlines. The probe servo keeps diagonally opposite wires A and A′ at the same potential because the voltage difference between the wires is the error signal of the servo. Maximum static error is 0.3 degrees. The voltage between wires *B* and *B′* is along a streamline and is equal to the potential gradient at that point times the wire spacing (0.6 in.). This voltage (usually between 0.05 and 2.0 volts and highest near electrodes) is amplified by a calibrated linear amplifier which excites a stator winding of the resolver. In addition, this voltage is used to keep the servo loop gain constant. Since the resolver rotor is coupled to the probe, the outputs of the rotor windings represent the X and Y components of the *B-B′* voltage. These outputs drive the X and Y velocity servos. Thus the probe velocity is proportional to the magnitude of the voltage between *B* and *B′* and is aligned along a streamline. The probe follows a streamline from one electrode to another until the operator stops its motion. Dc voltages from the X and Y servo-driven potentiometers cause the plotter pen to follow the probe.

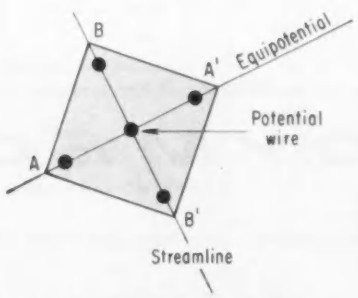

FIG. 2. Layout of the five-wire tank probe.

Wavefront positions are generated from the streamlines as follows: during the track along each streamline, the pen is lifted at regular time intervals. These are generated by a cam and switch driven by a servo with velocity feedback. Depending on the reference voltage (set with a calibrated knob), the intervals can be varied from 1 to 15 sec. The timing accuracy is plus or minus 0.5 percent or better, and the resolution is at least 0.1 percent. The wavefront is produced by manually connecting equal time marks on the different streamlines.

When tracking equipotentials, the probe servo operates as above, keeping wires A-A′ at the same potential. To select a particular equipotential the voltage on the central probe wire is compared with a reference (Figure 3, insert), and the error is fed to one stator winding of the resolver. The error voltage causes the probe to move at right angles to equipotentials until it reaches the right one. A fixed ac

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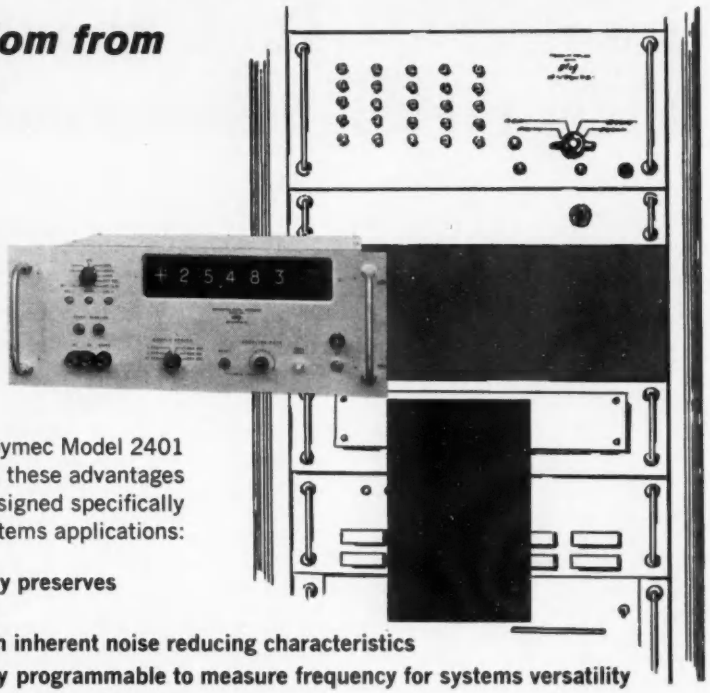

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Stability:	Greater than .01%/day, 1 v range and above.
Input Impedance:	1 megohm on 1 v and higher ranges: 100,000 ohms on .1 v range.
Sampling Period:	10 ms, 100 ms, 1 sec (crystal determined), or manual by local or remote control.
Sampling Rate:	90/sec with 10 ms sampling period to 9.8/sec with 100 ms sample period. Display time is adjustable from 100 ms to 8 sec, or continuous until manually reset.
Output:	Binary-coded-decimal for each digit; two-lines for polarity indication; one line for each range and operating mode.
Electronic Counter:	Max. count rate: 300 KC. 5-digit Nixie presentation. Accuracy: ± .01% ± 1 count.
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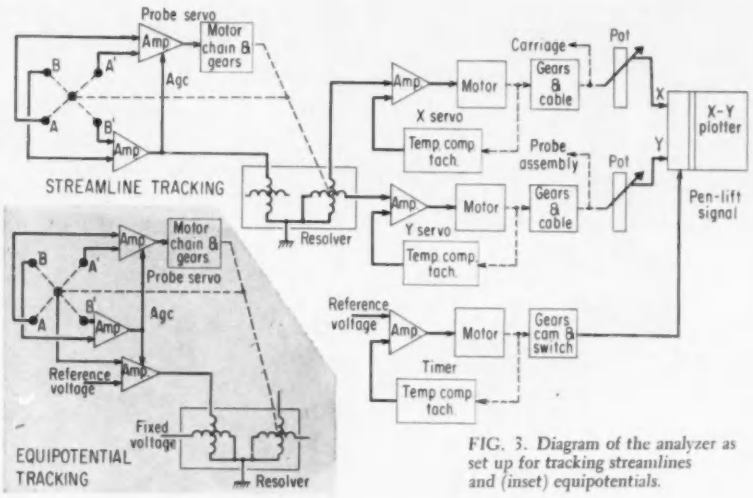


FIG. 3. Diagram of the analyzer as set up for tracking streamlines and (inset) equipotentials.

voltage is then applied to the second resolver stator winding, and the rotor voltages represent the X and Y components of this voltage. They drive X and Y servos at such speeds that the probe velocity stays tangent to the equipotential line.

To rout out the Styrofoam tank the probe servo assembly is replaced by a ¼-in. drill. The operator manipulates a steering crank and a speed control knob on the console to keep a cursor on the X-Y plotter over a contour line of constant depth.

The analyzer can also be used to measure the area inside a closed curve on the X-Y plotter. The operator guides the cursor one full circumference around the curve, and an instrument servo with an input signal from the tank unit computes the area.

Swinging Telescope Checks Hot Slab Widths

P. SPAINK,
English Electric Co. Ltd., England

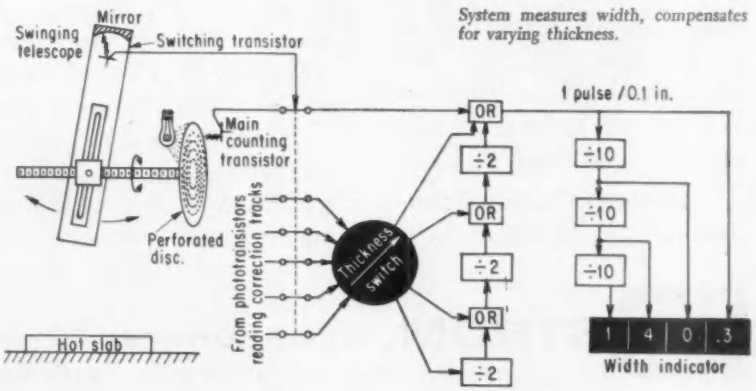
A novel width measuring system installed at the South Durham Steel Company's new South Mill uses a swinging telescope and transistor counters to measure hot slabs 2 to 15-ft wide with an accuracy better than plus or minus 0.5 in. The figure shows the basic system.

After leaving the roughing mill, a slab is arrested momentarily for measurement. A motor-driven 15-in. long telescope mounted 20 ft above the mill bed swings in an arc across the slab. Push buttons on the mill control pulpit control the motion. A 4-in. diameter mirror at the rear of the telescope focuses infrared radiation from the hot slab onto a phototransistor mounted at the mirror's 6-in. focal point. Edge definition is obtained from a 0.001-in. aperture slit ahead of the phototransistor. The slit limits the field of view on the slab to an 0.5 x 5 in. area, which is small enough that brightness compensation for varying slab temperatures is not required.

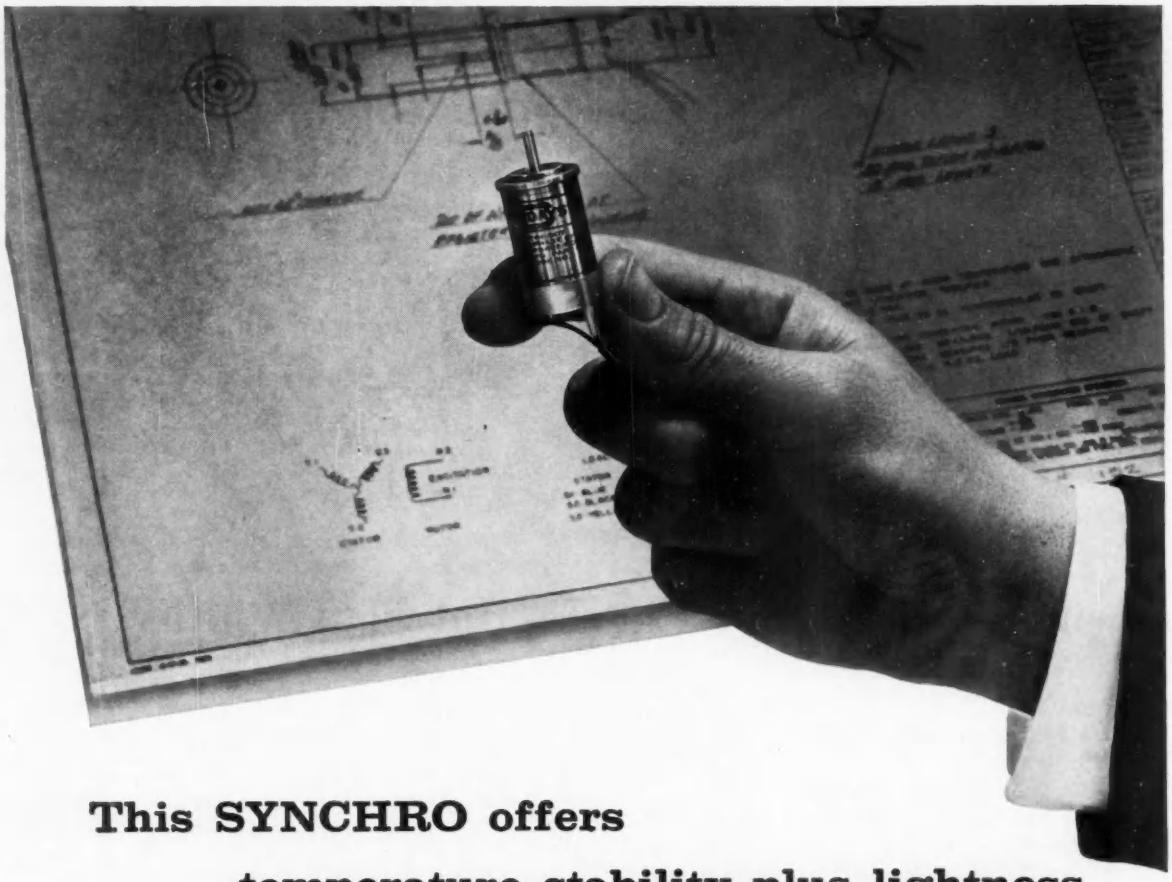
When radiation from the first edge of the slab reaches the phototransistor it switches on a series of pulse counting phototransistors which make the actual width determination. Distance pulses proportional to the tangent of the angle traversed by the telescope, and thus to the width, are generated from a perforated disc and light source. The disc is mounted on a threaded shaft and turned by a slotted nut on the telescope arm. The shaft thread pitch is such that one disc revolution is equivalent to a 6-in. traverse on the slab, and the disc perforations are dimensioned to produce one pulse from the measuring phototransistor for each 0.1 in. of width. These pulses are fed into a four-decade counter and accumulate until the telescope reaches the other edge of the slab and irradiation ceases. The indicated count is the slab width, accurate to within 0.1 in.

However, variations in slab thickness from 3 to 15 in. complicate the system. The effect of differing slab heights is to alter the switch on and switch off points of the telescope phototransistor and vary the count for slabs of equal width. Geometrical analysis shows that a linear relation exists between the slab thickness and the width correction required for each revolution of the counting disc to maintain accuracy. Using a 15-in. thick slab as the zero correction reference point, additional width signals equal to 0.025 in. per counting disc revolution are required for each inch of thickness reduction. Five switchable extra tracks on the disc allow one to eight extra pulses to be added to the main count in each disc revolution (6 in. of traverse). Three scale-of-two counters generate fractional pulses, the smallest correction being one additional pulse every eight disc revolutions.

As the slab leaves the roughing mill, an operator sets the slab thickness to the nearest 0.5 in. into the system with a 25-position switch. This determines which phototransistors are in the circuit. Eventually, the thickness information will be fed to the system automatically from the reversing mill screwdown position.



System measures width, compensates for varying thickness.



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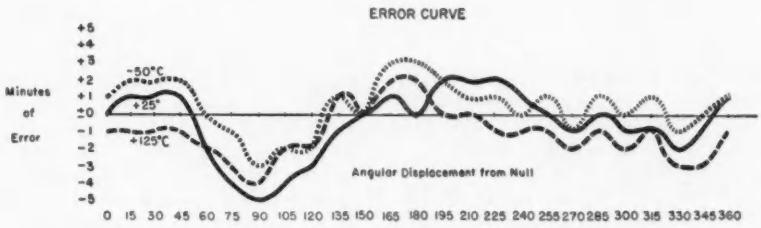

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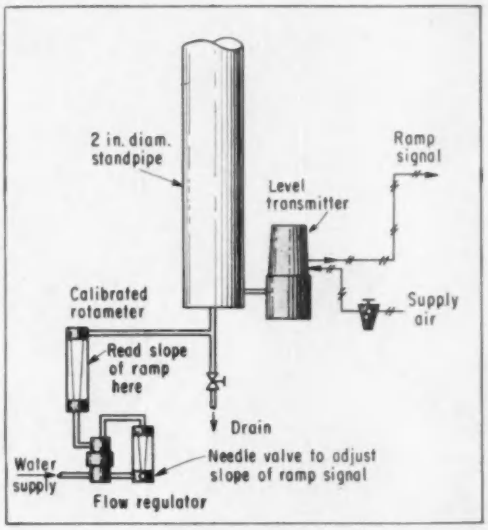
W. S. BUZZARD, *Fischer & Porter Co.*

Accurate, fast calibration of conventional process controllers and such control components as differentiators can often be accomplished by applying a ramp signal. While programmed cams and electronic generators can be used to develop ramps, they may be only partly satisfactory. Adjustment of ramp slope may be too difficult with motor-driven, cam-type ramp generators.

The hydraulic ramp generator shown here offers noise-free linear ramp signals and easily adjustable ramp slopes. A simple flow control arrangement consisting of a differential pressure regulator and an adjustable needle valve introduces water to a 2-in. diam vertical standpipe at a rate shown on the calibrated rotameter. Water level in the standpipe is then measured and transmitted as the ramp-signal output. The ramp slope, adjusted by the needle valve, is proportional to the rotameter reading.

By adding another flow control system at the drain and actuating shutoff valves at the water inlet and drain lines from the minimum and maximum signals of the level transmitter, it becomes possible to generate triangular signals. That is, the water in the standpipe will then continue to rise and fall, and the rate of rise and fall can be set independently.



Cams Combine to Program Simulator

STEWART T. BELDON,
Arma Div., American Bosch Arma Corp.

A new type of cam-driven function generator developed by Arma (Figure 1) is equivalent in performance to one using a regular three-dimensional cam but is less expensive to make and far more flexible. A cam magazine about 4 in. long contains 35 individual single-turn helical cams (Figure 2). These are grouped together on a common shaft to form a continuous spiral. The magazine is turned by a synchronous motor and gears, and the cams operate through followers, gearing, and potentiometers. Since the axial motion of the magazine is the same as the spiral rate of the cams, a cam follower sees an essentially continuous periphery on which the program is cut. Any cams can be replaced or interchanged to modify the program. Smaller and more rugged than tape or card programmers, the device can operate high power transducers directly.

The programmer shown is for a simulator used in training and evaluating the performance of B-52 fire control system operators. It has seven cam followers geared to switches and potentiometers that cause two simulated targets to appear on the gunner's radar display and provide a correct action signal to compare with his response.

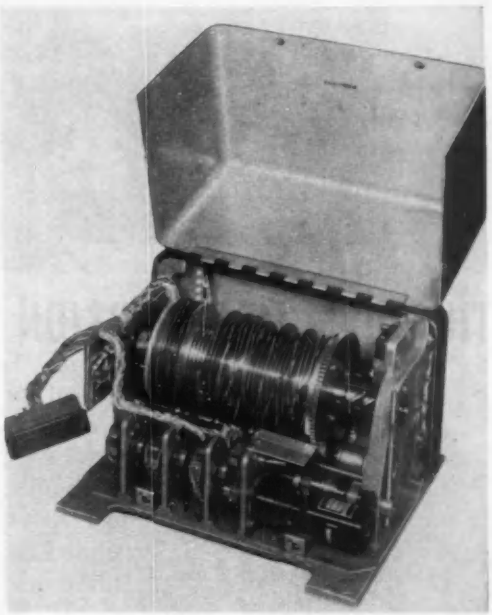


FIG. 1. The helical cam programmer.

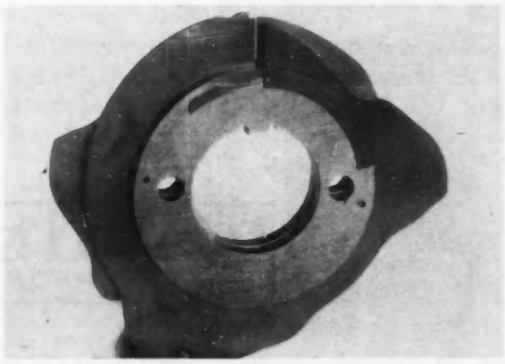


FIG. 2. Two adjacent cams removed from the magazine.

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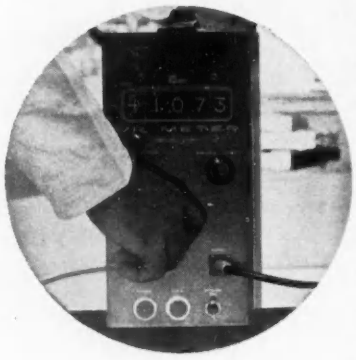

Other Features of the Model 2100: shockproof—withstands up to 50G shock; waterproof—can operate underwater; corrosion-proof—can't be damaged by salt spray or chemicals; specifications equal or exceed those of all high performance meters. Write for descriptive literature to Dept. CT-102, Industrial Division, Cubic Corporation, San Diego 11, Calif.

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Cubic manufactures a complete line of quality digital instruments, including a-c and d-c voltmeters, ohmmeters, ratiometers, scanners and printer controls.

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CORPORATION

Punched Tape Runs Subway Train

DESMOND STONE
McGraw-Hill News

The shuttle subway trains which ply back and forth between Grand Central Station and Times Square in New York City may soon be operated by a remote programmer. General Railway Signal Co. has developed and tested a system which controls all train movements by pulses sent through the rails. Programs for normal operation, weekends, peak traffic hours, and the like can be set up on punched tape. Photoelectric cells read the holes in the tape and convert them to various pulse rates for controlling the car motors, brakes, and doors. A train is started, sent to the opposite station, stopped, the signs rolled, lights changed, doors opened, advance warning of door closing given, doors closed, and the train proceeds back to the first station, all on a scheduled basis. If a train fails to start when a proceed signal is given, an indication is sent to the central office. If the train starts but fails to arrive at the other station, a similar indication is given.

During most of the run, train speed is maintained at 30 plus or minus 1 mph. The speed maintained prior to stopping is 5.6 plus or minus 0.2 mph. The stopping point will be within 2.4 ft of the desired spot. This figure includes variation due to load and grade, but there will be a further variation of 2.7 ft because of wheel wear unless compensation is provided.

Normally, dynamic brakes are used to slow the train from 30 to 5.6 mph. A graduated transition between the maximum dynamic brake rate (set at 3.0 mph per sec) and the minimum rate (set at 1.5 mph per sec) is under speed governor control and occurs at 16.5 mph. The 8-mph natural fade-out speed of the dynamic brakes helps provide an extremely smooth slow-down, equal in comfort to a well-controlled manually operated train.

GRS has controlled an unmanned 32-car Canadian National Railways freight train with a similar system, sketched in Figure 1. A track induction form of continuous control is used in preference to radio or induction from a pole line next to the track. Pulses are sent through the rails toward the motion of the train. Receivers mounted ahead of the lead wheels of the locomotive pick up the pulses, and the train axles complete the signal circuit. Three pulse rates are used to specify high, medium, or low speed, and a fourth frequency applies the service brakes. Electronic equipment, shown in Figure 2, compares the received frequency with the output of an axle-driven ac generator and manipulates the throttle and brakes to maintain one of the three speeds or stop the train. A key feature is that the absence of pulses will cause the emergency brakes to go on. Thus any discontinuity in the route or a train on the track ahead will stop the automatic train.

In this case, programming is built into the track. The locomotive can be given special instructions by way of fixed coils located between the rails at appropriate points. These track coils induce current in a similar coil mounted under the lead locomotive and connected to the control equipment. Depending on the frequency applied to the track coil, the train can be slowed for a curve, or dynamic braking can be applied.

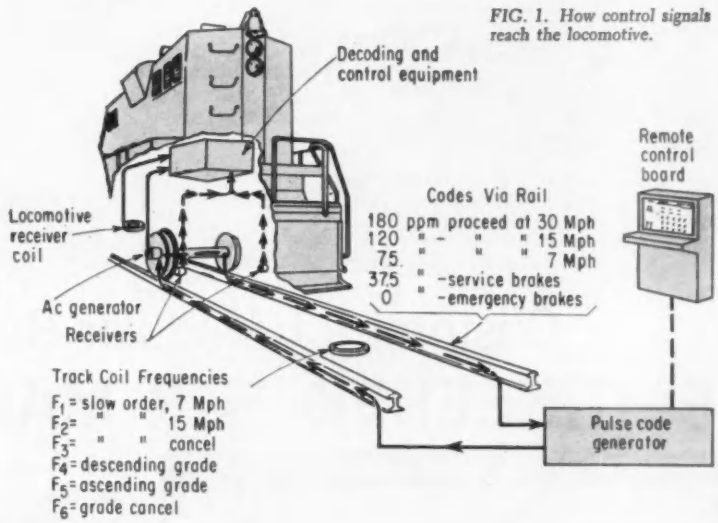
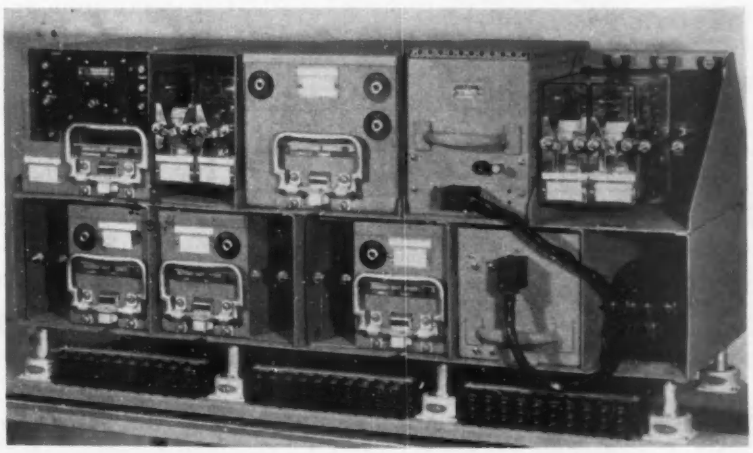
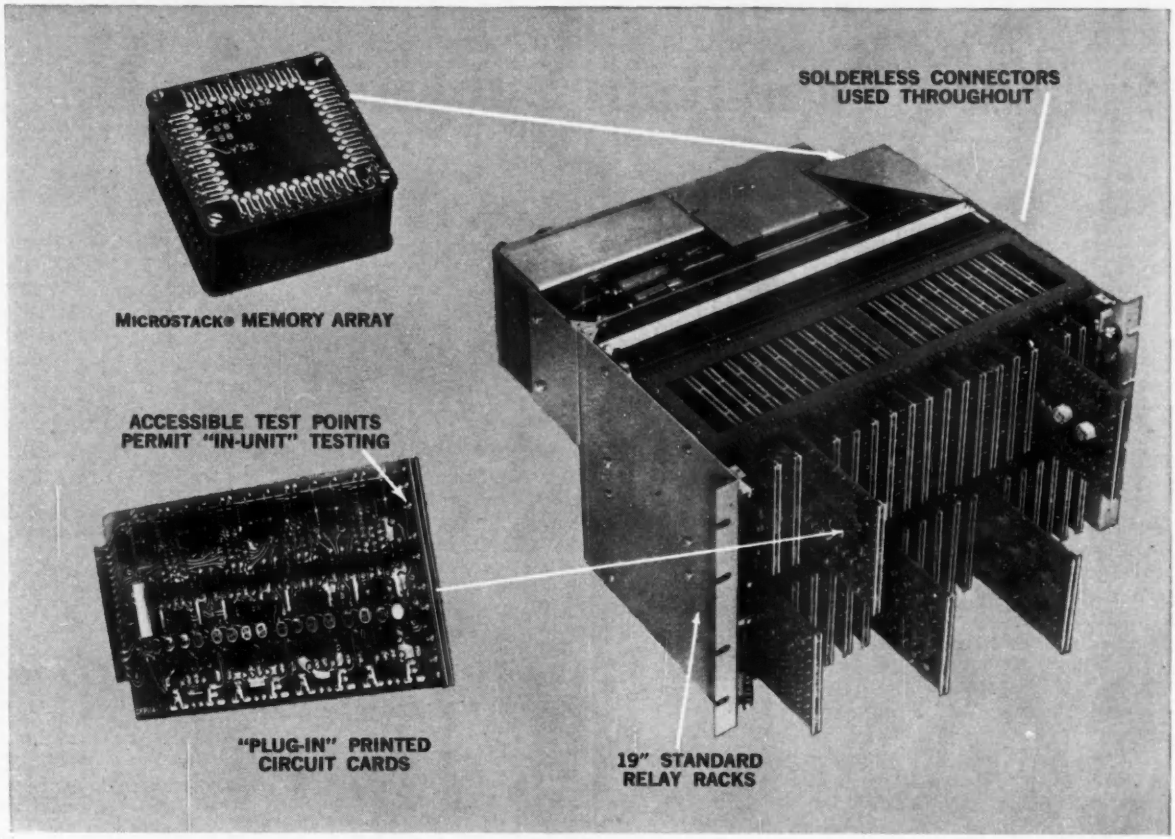

Decoding and control equipment
Remote control board
Codes Via Rail
180 ppm proceed at 30 Mph
120 " - " " 15 Mph
75 " " " 7 Mph
37.5 " -service brakes
0 " -emergency brakes
Locomotive receiver coil
Ac generator
Receivers
Track Coil Frequencies
F1 = slow order, 7 Mph
F2 = " " 15 Mph
F3 = " " cancel
F4 = descending grade
F5 = ascending grade
F6 = grade cancel
Pulse code generator

FIG. 1. How control signals reach the locomotive.

FIG. 2. Decoding and control equipment ready for the engine cab.



From General Ceramics Division of
INDIANA GENERAL CORPORATION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4 BASIC SERIES AVAILABLE				
Memory Series	M	K	L	J
Cycle Time — μ Sec.	10	6	5	3.3
Data Access Time — μ Sec.	4	2.5	3.5	2
Word Capacity **Note:** any bit length desired	32 to 32,000	32 to 32,000	32 to 32,000	32 to 32,000
Standard Types 1) Random Access	(See Note Below) X	X		
2) Sequential Interlaced	X	X	X	X
3) Sequential Non-Interlaced	X	X	X	X

NOTE: A combination of Random Access and either Sequential Interlaced or Non-Interlaced types are available in the "K" and "M" Series.

New GC modular design concept using standardized circuitry and in-stock modules speeds up deliveries of customized buffer and random access memory systems while improving reliability, cutting space requirements and simplifying maintenance.

Once again from General Ceramics, originator of the square loop Ferrite, comes a significant advance in the science of data handling — memory units that provide unequaled design flexibility.

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DIVISION OF INDIANA GENERAL CORPORATION

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KEASBEY, NEW JERSEY, U. S. A.

TECHNICAL CERAMICS, FERRITES AND MEMORY PRODUCTS

NEW PRODUCTS

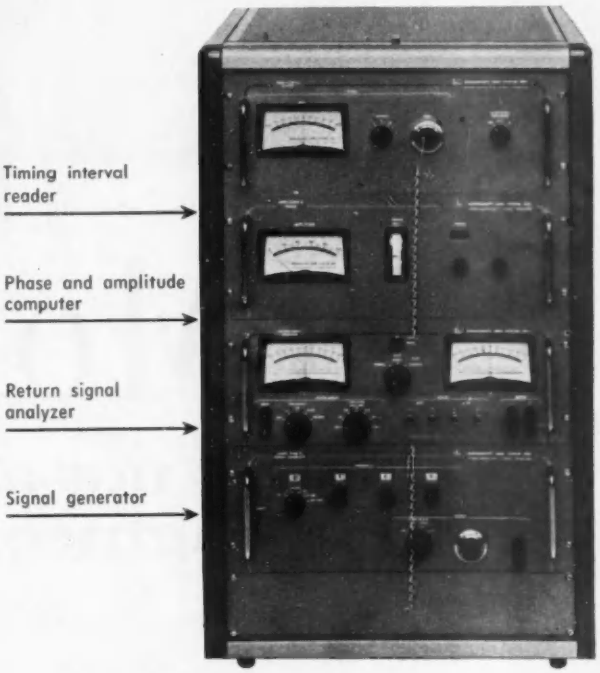
DYNAMICS ANALYZER OFFERS wide frequency range.

The Model 711 transfer function analyzer measures the frequency response of devices in the 0.01-200 cps range. The response of the unit under test is presented both as the in-phase and quadrature components and as the corresponding amplitude and phase shift. The analyzer is constructed in five sections: signal generator, return signal analyzer, phase and amplitude computer, and timing interval reader and a power supply.

Frequency range of the generator is 0.0100-999.0 cps with an accuracy to within ±1 percent of setting. The return signal analyzer accepts the signal from the test item and performs a Fourier analysis to separate the signal components. Maximum sensitivity is to 50 mv full scale. The timing interval reader speeds up low frequency testing. Indication of phase by the phase and amplitude computer is accurate to within ±2 percent; amplitude is accurate to ±0.25 db. Separate power supply has closely regulated ±300-vdc output at 175 ma.

Price for all five units is $4,855. A number of input-output accessories is also available.—Boonshaft and Fuchs, Inc., Hatboro, Pa.

Circle No. 309 on reply card.

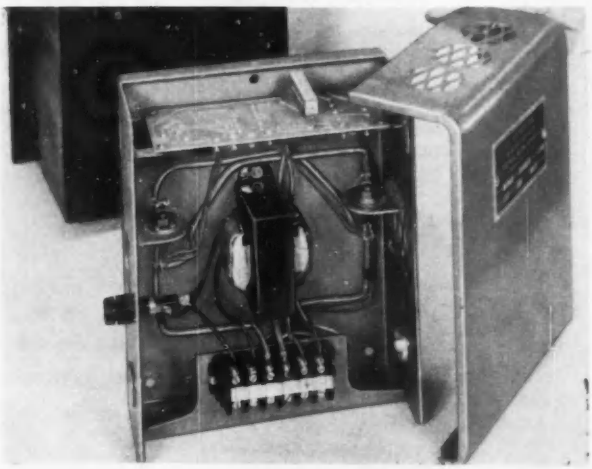


SCR'S CUT SPACE NEEDED for electric power control.

Substantial reduction in size is the main feature of this proportional power modulator. Designed originally to replace the bulky power controls used in electric furnaces (but suitable for any electric power control application), these new units use silicon controlled rectifiers to achieve a space saving up to 75 percent. Input to the device can be almost any electrical signal. Response times on the order of microseconds are possible.

The device, trade named pHayes-master, measures just 7 x 9 x 3 in. Models are available with ratings of 10, 15, and 70 amp at 115 or 230 volts, either single or three phase. A fully adjustable modulator using two SCR's ranges from $195 to $595. Models using one SCR and a silicon rectifier sell for less but handle range of 25-100 percent.—C. I. Hayes, Inc., Cranston, R.I.

Circle No. 310 on reply card.



COMPUTER OUTPUT DEVICE films two pages a second.

Magnetic tape output of digital computers can be converted to plain language on 16-mm microfilm at speeds approaching 20,000 characters per sec (sustained, 15,000) using the DACOM—DAtascope Computer Output Microfilmer. Complete pages containing as many as 8,064 characters can be photographed on the film in about ½ sec. Using a unique character generation technique that employs a flying spot scanner, DACOM decodes the tape input to full page representations on a cathode ray tube and then photographs these pages on low speed, small grain-size film.

Film representing the computer output can then be

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For control equipment, display equipment, and design of analog and display circuits.

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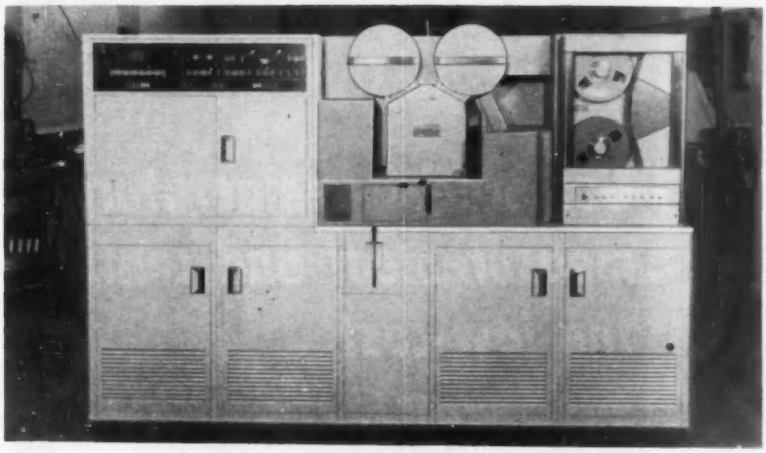
To design entire computer systems. Advanced degree preferred.

SENIOR ENGINEERS
For relay logic and relay switching design and application to advanced digital techniques.

PROJECT ENGINEERS
For technical project management of development and design engineering and customer liaison and manufacturing. Responsibilities include project direction, control and proposals for improvement and extension of digital system capabilities.

PROJECT ENGINEERS
For visual data handling and analog data processing, employing direct view storage techniques, alphanumeric readout devices and projection systems.

For complete details on these positions contact Mr. O. S. Knox at RCA West Coast.



processed and fed to visual readers where individual page paper copies can be made, or continuous hard copy can be made in high speed processors which will soon be made available. But emphasis in the DACOM system is on microfilm records rather than hard copy.

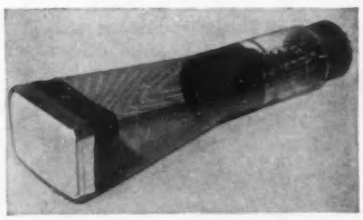
Characters (up to 64) are contained on a glass slide as are page format (for business records, for instance) and a group record format (a "title page"). Any symbol can be incorporated on the character slides, including lines at various angles, so the system is suitable for point plotting, reproduction of logic diagrams, etc.

Compared to a standard 500 line per min paper printer, DACOM is 13 times faster based on a full line of characters (130 for the printer, 126 for DACOM). But since DACOM is a *character* per unit time system rather than a *line* per unit time device, DACOM would be 130 times faster on a 10-character line basis, for example. This mode of operation also saves computer time.

Input in IBM 700 Series codes can be accommodated; modifications to the decoder or a tape translator is needed to accept other computer codes. Price with point plotting and random access features: $285,000; monthly rental: $8,000.—Recordak Corp., Sub. of Eastman Kodak Co., New York, N.Y.

Circle No. 311 on reply card

DATA HANDLING & DISPLAY



3-BEAM CRT

The Type 7BFP is a new triple beam 4 x 6 in. rectangular cathode ray tube with electrostatic focusing and deflection. Each beam is independently controllable with common accelerator and heater connections. Linear post accelerator combines with advanced gun design to provide high deflection sensitivity and brightness. Three simultaneous displays are possible since each beam scans a separate screen area. Deflection factors range from 40 to 73 vdc per in. Price: $500.—Electronic Tube Div., Allen B. Du Mont Laboratories, Div. of Fairchild Camera and Instrument Corp.

Circle No. 312 on reply card

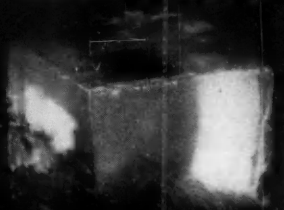
MULTISCOPE DISPLAY

Computer maintenance testing, real-time monitoring, and rapid information display are some of the uses of this general purpose alphanumeric display system. With its stored memory and character generator it acts as a link between a computer and any number of the manufacturer's scopes. Total character output is 125,000 per sec. The magnetic stored memory, with full random access and 8-microsec cycle time, has a capacity of 1,024 24-bit words, in addition to automatic message regeneration. Character size is controllable, and repertoire has 45 characters including decimal numbers, English alphabet, miscellaneous marks, and ruling lines. A character generator, input-output control, and memory

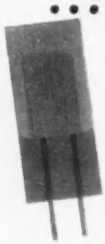
+2000°F

-450°F

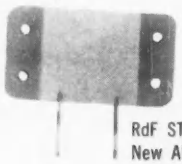
Get precise temperature measurement and control the low-cost easy way...



...insist on RdF STIKONS & STRAPONS



RdF STIKON BN Series



RdF STIKON New APM Series

RdF STRAPON RN-100

RdF STRAPON RNM-100-1

RdF INDICATORS

RdF STIKON® resistance thermometers for surface temperature measurement were pioneered by RdF Corporation (formerly Arthur C. Ruge Associates, Inc.). These versatile transducers are characterized by millisecond response, high sensitivity, accuracy, stability and high output. Recent developments in adhesives now make it possible to bond RdF STIKONS easily and quickly to virtually any surface. Available in a wide variety of grid styles and carrier materials. Latest addition to the line is the APM Series with temperature ratings of —450° to 2000°F.

RdF STRAPON resistance thermometers, a modification of the RdF STIKON, are mounted on a stainless steel shim overmolded with silicone rubber. These rugged, re-usable sensors can be strapped to the outside of a pipe to measure the temperature of fluid inside without shutting down a process, interrupting flow or cutting holes in pipes. RdF STRAPONS are designed to operate at continuous temperatures from —100° to 500°F.

RdF PROBES — To supplement the established capability of RdF resistance thermometers for surface measurements, RdF Corp. offers a complete line of standard, mounted and miniature probes for measuring temperature in any situation.

RdF PORTABLE INDICATORS — A series of low-cost, direct-reading temperature indicating instruments for use with RdF resistance thermometers. Easy to use, accurate, dependable. Battery or AC power supply optional.

If you have a temperature measurement/control problem, contact us for the name of your nearest RdF sales engineer. Write today for RdF STIKON Catalog and Price List #T-59 and for RdF Products Bulletin #T-60A.

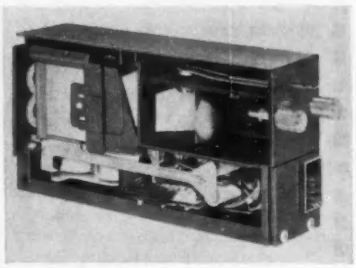
RdF Corporation
Hudson, New Hampshire

Nashua, N.H., TUxedo 2-5195 TWX NASH 188-U

NEW PRODUCTS

are included in the price of $25,000 per operator station.—Data Display, Inc., St. Paul, Minn.

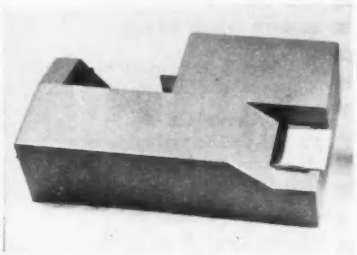
Circle No. 313 on reply card



BCD READOUT

Replacing the manufacturer's Slide Plate readout unit, this new Bina-View self-decoding display device accepts any binary coded decimal code up to six bits, does its own translating, and displays the proper character. A low power device, the readout may be operated with as little as 10 mw of signal. Operation is electromagnetic, and speed of display is up to 20 characters per sec. Character displayed is 1⅜ in. high. A 12-character readout sells for $50; 32 and 64-character units will also be available.—Industrial Electronic Engineers, Inc., No. Hollywood Calif.

Circle No. 314 on reply card



SINGLE OR MULTIPLE FEED

Designed for desk top operation (dimensions: 19 x 6 x 11 in.), this tab card reader has a maximum speed of 20 columns per sec. An 86-column emitter indicates which column is being read on the card. Each of the 80 information columns can be programmed to be read, skipped, or denote begin or end field. Columns 81 through 86 control card feeding, stacking, etc. There are two models: one manually operated for single card insertion and a multiple feed unit that takes about 500 cards. Both models

This is the Clary Model 2000 series Militarized Printer. This is the one that operates flawlessly... that prints characters in a straight line within .001 inch... it even withstands such severe conditions as a 50g shock of 7 milliseconds duration and 10g's of vibration throughout the frequency range of 2 to 12,000 cycles per second.

Constructed on a sturdy panel for rack mounting, it contains all the necessary electronic equipment for data decoding, digit selections, and control functions. It employs a simple, clean, basic design that makes it adaptable to print the output from a wide variety of devices, including computers, digital voltmeters, shaft position transducers, electronic counters, and digital clocks. In addition, it is ideal in industrial applications where continuous, unfailing operation is required.

this is the printer that can take it!

Clary Model 2000 Series Printer

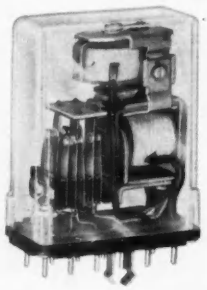
For complete information on how the Clary Model 2000 series printer can help you, write today for Engineering Bulletin S-120.

Clary CORPORATION
San Gabriel, California

CIRCLE 173 ON READER SERVICE CARD 173

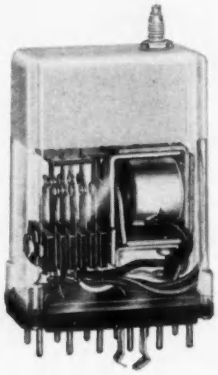
2-COIL "MEMORY" RELAY

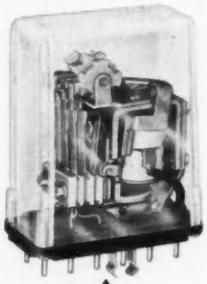
Mechanical latch, electrical reset, Frame 255, with DP-DT; TP-DT; or 2 N. O. and 2 N. C. contacts.



TIME DELAY CONTROL RELAY

Frame 235—Combines a solid state adjustable timing element with a Frame 219 relay unit. Timing ranges: 0.2 to 18 seconds; 2.0 to 180 seconds.



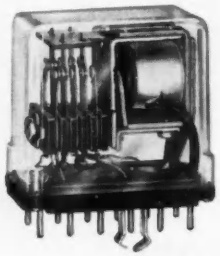


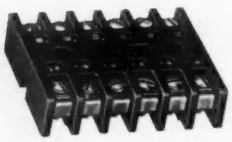
SINGLE COIL SEQUENCE RELAY

Frame 211—Provides thousands of control sequences, permits simplified, low cost sequence control.

GENERAL PURPOSE CONTROL RELAY

Frame 219—Available in 3 standard contact arrangements.





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These compact Dunco relays in matching plug-in designs are causing a quiet revolution in simplifying and economizing modern control of many kinds. Four moderately priced types provide practically any operational circuitry feature. Life, dependability, insulation and other characteristics meet the most critical industrial control specifications.

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STRUTHERS-DUNN, Inc., Pitman, N. J.

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NEW PRODUCTS

have a stacker which can accommodate approximately 500 cards. Single card model price: $1,200.—Systronics, Torrance, Calif.

Circle No. 315 on reply card

PORTABLE RECORDER

A magnetic tape recorder designed for precise data acquisition in the field or in mobile equipment has just been introduced. Weighing only 10 lb and measuring 5 x 7 x 10½ in., the Model PRM-500 requires dc power of 22-30 volts, 20 watts max or 115-volt, 60-cycle ac. Frequency response is from dc to 100 kc ± 3 db at 30 ips, direct; dc to 10 kc, FM. (Upper end proportionately less at slower speeds.) Up to 96 min of 7-channel data can be recorded at 1⅞ ips (6 min at 30 ips) on 900 ft of ½-in. tape wound on 5-in. reels. Wow and flutter are within 0.2 percent rms dc to 300 cps. Price: $2,500 to $8,000.—Pacific Electro Magnetics Co., Palo Alto, Calif.

Circle No. 316 on reply card

PLUS . . .

(317) Large size **electroluminescent readout lamps** are now available from **Westinghouse Electric Corp.**, Pittsburgh, Pa., having figures with a maximum size of 2⅜ x 4 in. that can be read from up to 150 ft away. . . . (318) **Remington Rand Univac Div. of Sperry Rand Corp.**, has introduced a **photoelectric key verifier** for verifying punched cards including the standard 90-column type and others. . . . (319) Four new **compact receivers:** a single function generator, a dual function generator, an indicator/totalizer, and a panel mounted totalizer have been added to the telemetering instrument line of **B-I-F Industries, Inc.**, Providence, R.I.

Circle 317, 318, or 319 on reply card

RESEARCH, TEST & DEVELOPMENT

120-CIRCUIT TESTER

Said to be the largest automatic high voltage tester ever built, this new analyzer checks continuity, insulation

this is the Brush Mark II . . . anyone can plug it in put it in writing anywhere

There is no direct writing recorder on the market that approaches the compact Mark II in sheer usefulness. It is a completely integrated engineering tool that can be operated by anyone . . . in the shop or in the field . . . for countless research or design requirements. Every function necessary for uniform, crisp, easily reproduced readouts is "built-in". The Mark II gives you two analog channels plus two event markers; 4 chart speeds; DC to 100 cps response with 40 mm amplitude; 10 mv/mm sensitivity; high input impedance. Ink or electric writing models. Immediate shipment from stock.

brush INSTRUMENTS

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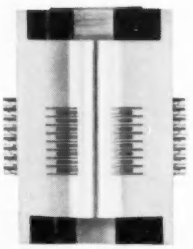
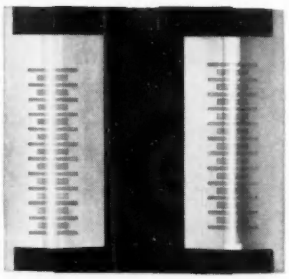
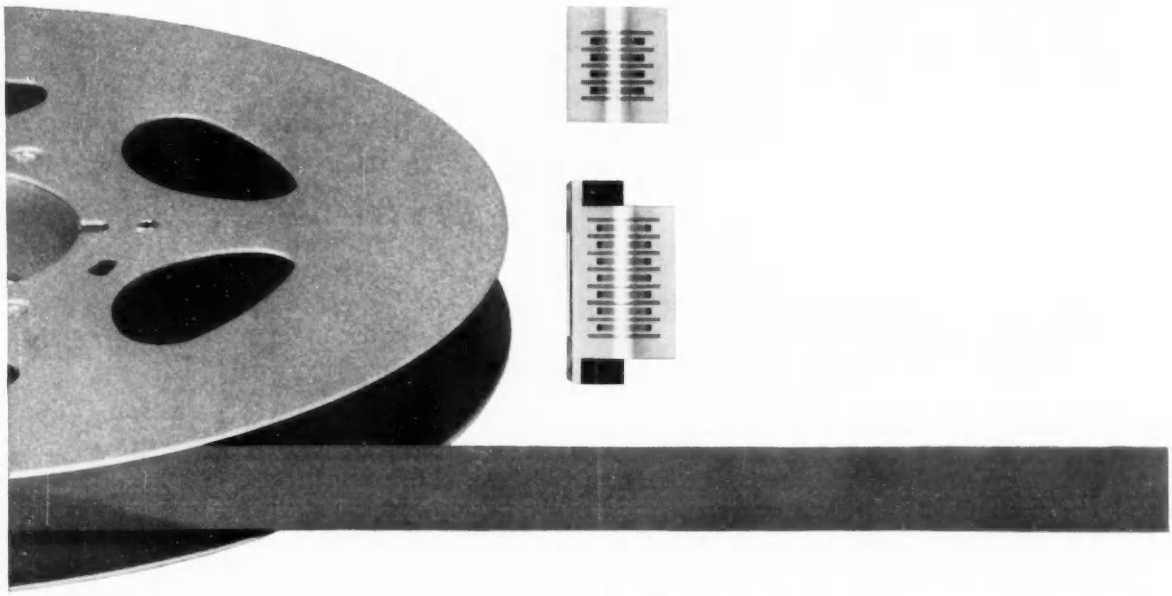
37TH AND PERKINS — CLEVELAND 14, OHIO

standard heads by Brush fill 90% of all Magnetic Head Applications







Why such an all-out claim? Because only Brush has kept pace with the many design requirements in recording technology. Continuous analysis of current and future trends enables us to maintain a design improvement program incorporating all field-proven advances in our *standard* heads. It's a must . . . to satisfy *all* customer requirements. The result? We've been able to standardize and meet all but a few highly specialized applications. You save engineering and testing time . . . and money. If you're one of the few with a "special" problem, Brush obviously has the engineering capability and manufacturing facilities necessary to fulfill *your* magnetic head application. With both standard and special heads, detailed mechanical drawings and specifications plus actual electrical characteristics are available *before the fact.* You can accurately predict system performance without costly time-consuming tests. *Write now for our design and specification bulletin "Optional Characteristic Heads".*

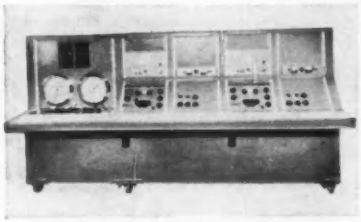
brush INSTRUMENTS

DIVISION OF CLEVITE CORPORATION

37TH AND PERKINS CLEVELAND 14, OHIO

resistance, and dielectric strength of cables with up to 120 conductors. For continuity, lower and upper resistance limits are presettable from 0.5 to 200 ohms. High pot test may be dc or ac with voltage from 0 to 5,000 volts. Acceptable leakage current is adjustable from 1 microamp to 2½ ma dc or 0.5 ma to 3 amp ac. Insulation resistance test is made at 500 volts with minimum limit adjustable from 1 to 50,000 megohms. Analyzer also checks itself.–Associated Research, Inc., Chicago, Ill.

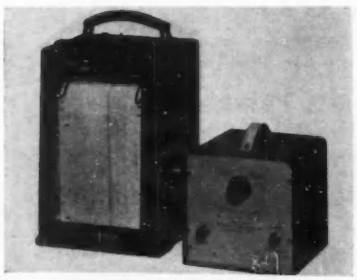
Circle No. 320 on reply card



HIGH ACCURACY CALIBRATOR

Load cell transducers are accurately calibrated using the new Model 256 system which calibrates these cells from 5,000 to 1 million lb within 0.05 percent of reading. Three overlapping sets of the manufacturer's force calibrators are used. The hydraulic press is arranged to handle tension and compression loads with a stroke opening from 0 to 96 in.–Gilmore Industries, Inc., Cleveland, Ohio.

Circle No. 321 on reply card



NEEDS LITTLE ATTENTION

This expanded scale recording voltmeter has been designed to monitor voltage fluctuations in installations requiring extended unattended operation. The voltmeter, which has no tubes or transistors, operates a recorder that provides chart deflections with amplitudes said to be two to

with this new ultra-low distortion,

stable-amplitude oscillator

When the specs get critical, you need an oscillator that won't add distortion and instability of its own. Here's a stable-amplitude, low-distortion oscillator — Krohn-Hite's new Model 446 — that gives you a *cleaner* sine wave than any other oscillator you've ever worked with!

Amplitude stability is ultra-high: 0.001 db (0.01%), due to a unique infinite-gain AVC circuit (patent pending). Amplitude bounce near line frequency is no longer a problem — less than 0.05%. Distortion — phenomenally low: less than 0.01%.

But that's not all. The 446 push-button oscillator offers continuous frequency coverage from one cycle to 100 kc. Voltage output is continuously adjustable from 0 to 10 volts, with infinite resolution all the way.

And when you need *power* along with stable amplitude and low distortion, team up the Model 446 oscillator with Krohn-Hite's Model UF-101A ultra-low distortion 50-watt amplifier. Here's an amplifier which preserves the stability and distortion-free characteristics, even at a full 50 watts. Frequency response of the amplifier — from 20 cps to 20 kc at full power. A convenient load impedance switch offers a choice of 1, 2, 4, 8 and 225 ohms.

Together, this oscillator and amplifier provide a highly-stable, low-distortion, variable-frequency Power Source (Model LDS-115) — for the most critical meter calibration or measurement needs. Send for technical literature on these new Krohn-Hite instruments.

See us at IRE—Booth 3708-3710

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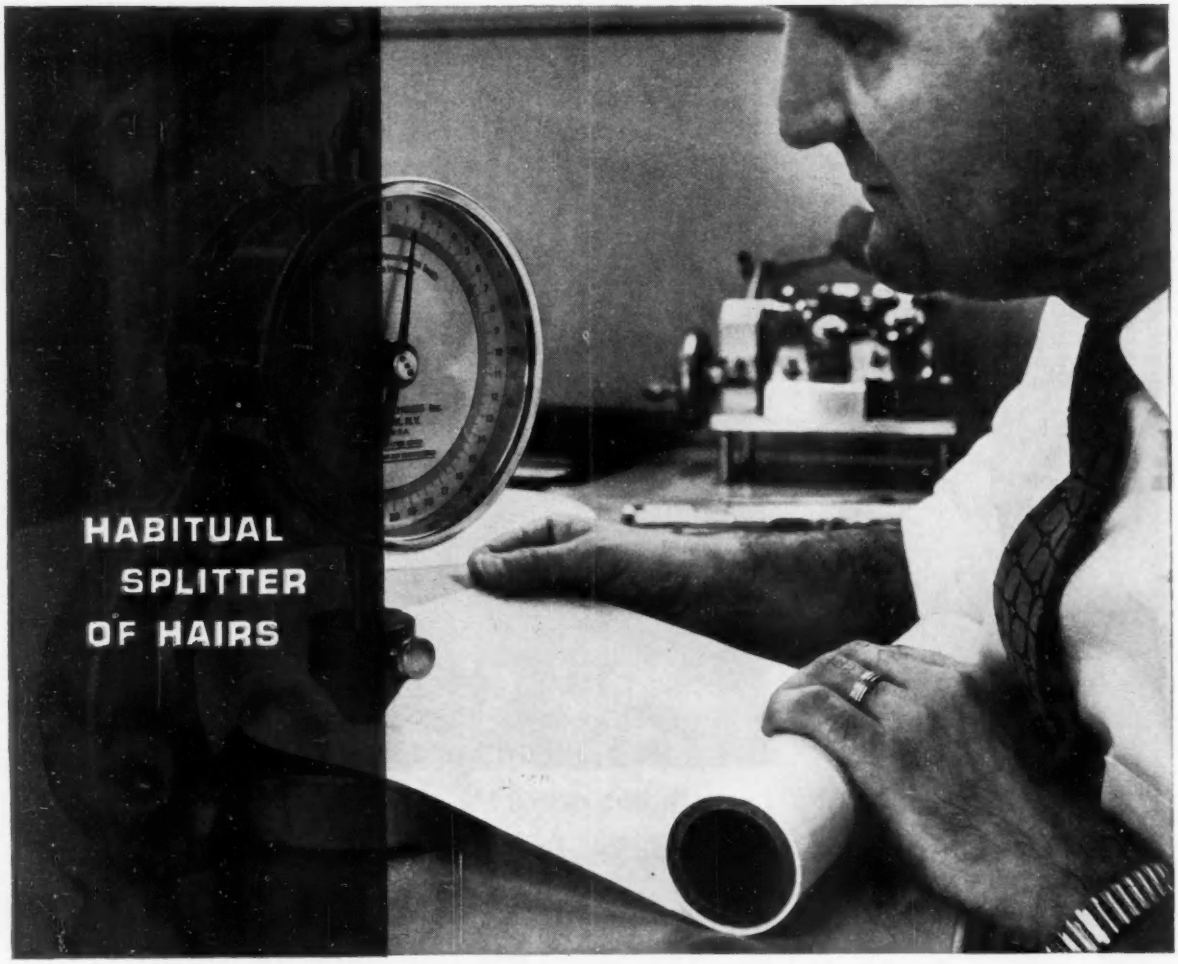


. . . because a mil can matter greatly in RECORDING CHART PERFORMANCE

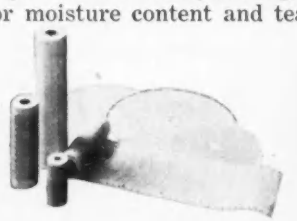
Even a fraction of a mil can bulk large in the thickness of a recording chart. That's why John Mazurowski and his thickness micrometer are so important to chart users.

A process change in an eastern oil refinery, for example, called for a longer strip chart in a temperature recorder — but the diameter of the roll could be no bigger than before. GC engineers solved this problem by working with our paper mills to reduce chart paper thickness from 0.00275" to 0.0019" while preserving strength and flexibility.

To make sure our charts meet the requirements of your instruments, GC engineers test paper stock for moisture content and tear-strength, too. This rigid inspection of paper that is produced exactly to GC specifications is a major reason why GC Recording Charts consistently fulfill their promise of accurate performance.

Other reasons for GC quality include our special formula printing inks, our exclusive innovations in plate-making and printing, and the scrupulous humidity control maintained throughout our manufacturing and storage areas.

GC Recording Charts have become standard equipment in more than 5,000 plants today. We stock more than 15,000 different charts—and will design and produce accurate special-purpose charts. Send for our newest Stock List—and for sample charts.



RECORDING CHARTS

GC Recording Charts are accurate

New booklet helps solve SPECIAL CHART problems

If you have a unique recording or control problem which a stock chart won't fit, GC's experience will work for you.

This free booklet, "Points to Specify in Special Chart Design," offers many useful tips to consider before specifying or designing a special chart. It suggests possible types of paper, sizing of punched holes, ink colors, overprinting, grid line widths, etc.

GC service—and this booklet—can eliminate false starts and wasted time. Let us serve you. Just send this coupon.

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NEW PRODUCTS

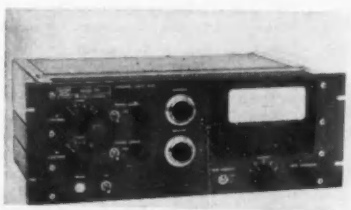
three times greater than standard voltmeters. Hookup requires only 5-10 min. Unit responds fully to a 100-millisec pulse. The unit is sensitive to fluctuations down to 0.25 volt in a 120-volt system. Called Model 1122B-60, the voltmeter recorder combination is available rack-mounted or with a carrying case.—Brenner-Fiedler & Associates, Inc., Los Angeles, Calif.

Circle No. 322 on reply card

CALIBRATES TORQUE DEVICES

An accuracy to within ±0.2 percent is claimed for this torque calibrator which may be used as a primary standard for measuring and calibrating torque devices. Three scales, calibrated in both ounce-inches and gram-centimeters, provide a measuring range of 0.5 to 40 oz-in. (20-2,800 gm-cm). Three calibration weights are included to allow operation in high, medium, or low range. Nondynamic torque can be checked in seconds. The device is portable, and provision has been made for mounting special fixtures on the front panel. Price: $245.—Waters Manufacturing, Inc., Wayland, Mass.

Circle No. 323 on reply card



DIFFERENTIAL METER

Temperature, pressure, strain, or light level can be measured using transducers attached to this differential current meter. Two transducer currents can be measured separately or differentially with the differential maintained by connecting the output of the instrument to a null balance servo. The model may be used with any null balance type of recorder. Dynamic range is 100,000, and the unit will measure currents as low as a millimicroamp full scale. Frequency response is ½ cps at the lowest range increasing to 30 kc at the least sensitive range. Preamplifiers with gain of 1,000 are available for low level work. Price is $1,195.—Eldorado Electronics, Berkeley, Calif.

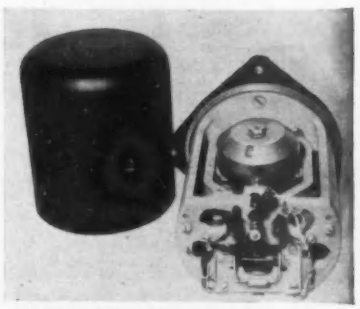
Circle No. 324 on reply card

PRIMARY ELEMENTS & TRANSDUCERS

HIGH OUTPUT PRESSURE PICKUP

A line of miniature piezoresistive pressure transducers has been introduced that features high output and excellent temperature response. With negligible vibration sensitivity (0.0008-0.008 mv/volt/g the solid state devices have an output voltage about 20 times that of wire strain gages; sensitivity is 40 mv/volt. Models are available in three ranges, from 0 to 25, 100, or 500 psig. Temperature range is −65 to +350 deg F. Natural frequency is greater than 4 kcps, and dynamic frequency response is 0-1,000 cps. Price: $325—Gulton Industries Instrumentation Div., Metuchen, N. J.

Circle No. 325 on reply card



REUSABLE SPRING GYRO

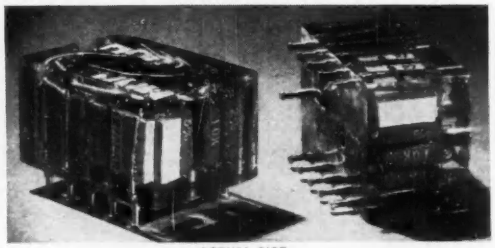
Shown uncovered above is a new low cost spring energized gyro designed to provide an inertial reference for short duration ballistic vehicles. The device is said to give full performance for a minimum of 25 firings, but must be disassembled and rewound before each. Unlatching is by one or two 28-vdc dimple motors followed automatically by uncaging, which takes a minimum of 100 millisec. Full speed of 3,300 rpm is reached in 100 millisec, and rundown time is 7-9 min.

Transistor Logic Elements for Defense

Use these logic modules for easier, faster, computer design

Encapsulated elements operate at high frequency over wide temperature range

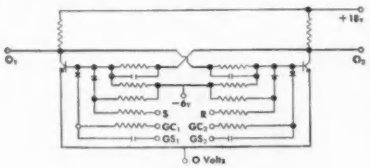
- **Fast switching speed of 1 mc/second**
- **Standard 6 volt logic**
- **Rugged, uniform packaging**



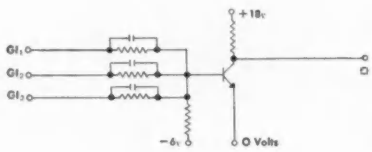
ACTUAL SIZE

Series M Transistor Logic Elements now provide maximum reliability and high frequency performance over an extended temperature range of −40 C to +125 C. Pre-designed for immediate use in breadboard, prototype or production equipment, these compatible logic modules find versatile defense applications in digital computer and data handling systems. Encapsulation in high-temperature epoxy material, semi-transparent for easy inspection of internal assembly, affords protection from extreme environmental conditions of humidity, shock and vibration. Metal feed-through sleeves improve mounting flexibility, while uniform packaging and terminal arrangement facilitate interconnection of modules.

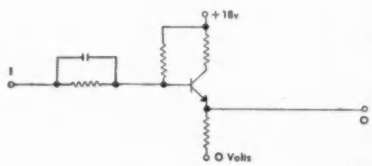
Reasonably priced and available for prompt delivery, General Electric Transistor Logic Elements are manufactured from thoroughly tested, quality components. These saturating and resistance-coupled modules are also offered in circuit and packaging variations, custom designed to meet specific engineering requirements.



Transistor Binary (Type M-264) **—provides two gate control inputs, two gate signal inputs, and two direct resistance inputs for the set and reset of the flip-flop. Intended for use in counters and shift registers, it drives up to four, fully loaded, Series M Transistor NOR-Gates at each of the two outputs.**



Transistor NOR-Gate (Type M-134) **—performs pulse inversion and logic functions OR and AND. Each of the two separate elements of this common emitter switch drives four additional, fully loaded, Series M Transistor NOR-Gates. Three inputs are furnished for each element.**



Transistor Emitter Follower (Type M-31-10) **— consists of two separate elements with individual input and output terminals. Both elements are capable of driving up to ten, fully loaded, Series M Transistor NOR-Gates. Applications are found in impedance transformation and in driving logic elements without inversion or significant degradation in the transmitted pulse.** 176-52

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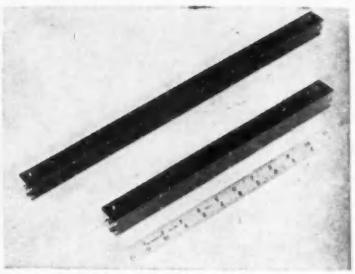
NEW PRODUCTS

Angular momentum is 737,000 gm-cm²/sec with moment of inertia of 2,116 gm-cm². Drift measured after 30 sec of operation is less than 1 deg for outer gimbal, 6 deg for inner gimbal.—Model Engineering and Manufacturing Corp., Memcor-Courter Products Div., Boyne City, Mich.

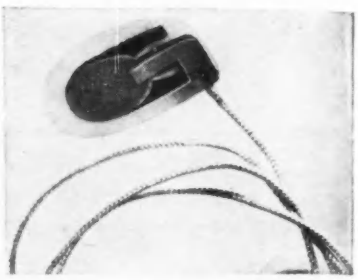
Circle No. 326 on reply card



30-IN. STROKE

Designed for either ac or dc operation, this linear motion potentiometer has a sensitivity of 5 millionths of an in. with claimed infinite resolution over any stroke up to 30 in. Maximum amplification is 350 volts per in. of shaft movement. Cross sectional area is 1 in. Because the shaft is free to rotate, shaft binding is eliminated. Life is guaranteed to be in excess of 10 million strokes, depending on the circuitry. — Computer Instruments Corp., Hempstead, N. Y.

Circle No. 327 on reply card



NORMAL FORCES ONLY

With a thickness of only 0.035 in. and an over-all area of 1 sq in., this pressure transducer is the thinnest on the market, according to the manufacturer. It responds only to normal forces, is hermetically sealed, and has a pressure sensitive area of 1 sq cm. Operating range is from 15 in. Hg vacuum to 100 psi. The transducers may

be suspended or applied directly to the place or curved surfaces in which pressure is measured. Elastic elements are thin sheets of embossed alloy, the dielectric is mica, and the covers are Saran film. Price: $40.–Spitz Laboratories, Inc., Yorklyn, Del.

Circle No. 328 on reply card

PLUS . . .

(329) A 1 cu. in., 3-oz. temperature compensated **strain gage accelerometer** (smallest such device available), made by **Consolidated Electrodynamics Corp.**, Sub. of Bell & Howell Co., Pasadena, Calif., measures accelerations parallel to mounting surfaces in ranges from ±5 to ±500 g. (330) Offered by **Sage Instruments, Inc.**, White Plains, N. Y., low capacity **load cell** is available in several models in ranges covering 0-50 lb and is designed primarily to measure forces exerted by muscles and for other physiological uses.

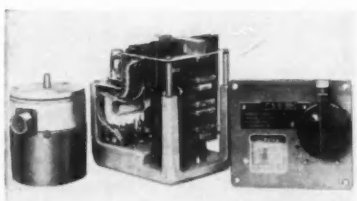
Circle No. 329 or 330 on reply card

CONTROLLERS, SWITCHES & RELAYS

FOR DATA SAMPLING

This new data scanning relay for low level, high speed data acquisition features long life and an electromechanical relay coil. Two replaceable sealed cartridges contain the armature and fixed contacts. Magnetic coupling to the relay coils permits dpdt configuration. Simplicity, absence of wiping contacts, and rugged construction allow service life exceeding 200 million operations. Weighing just 2 oz, the units measure ⅝x1⅛x1½ in. Price: about $55.—Magnavox Research Laboratories, Torrance, Calif.

Circle No. 331 on reply card



POSITIONS MACHINE TOOLS

Built for machine tool applications, this positioning control can provide settings to 0.001 in. over a 30-in. travel. Resolution is claimed to be better than

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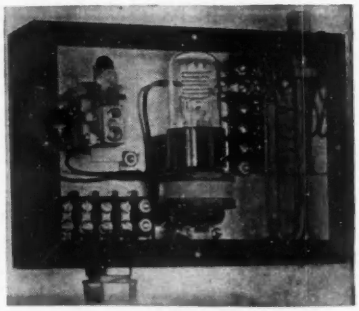
491/3

NEW PRODUCTS

one part in 30,000. The control shown includes position sensor, solid state amplifier, and digital readout. Amplifier may drive a rotary or linear actuator or may control other hydraulic or electric drives. A crossover circuit provides fast traverse and transfer to slower speeds as preset position is approached.—Jordan Controls, Inc., Milwaukee, Wis.

Circle No. 332 on reply card



PROTECTS PUMPS

Over-pressure protection for forepumps, diffusion pumps, and other vacuum pumps is provided by the Televac vacuum actuated control switch. The new device solves the problem of conventional vacuum actuated switches in which contacts are exposed to system oils, which often insulate the contacts, causing them to fail to make. The Televac uses the familiar principle of the mercury manometer, enclosing four separate fixed-control contacts and a common return contact inside a partially mercury filled U-tube manometer. Vacuum changes corresponding to unsafe conditions in the system change mercury levels, initiating proper contact closure to correct the situation. Operation range: 1-300 mm Hg; current capacity: 10 amp at 115 volts, 5 amp at 220 volts.—The Fredericks Co., Bethayres, Pa.

Circle No. 333 on reply card

PLUS . . .

(334) **Rotary Devices Corp.** Englewood, N. J., is now producing a line of **commutating, programming, and sampling switches** that are normally motor driven but may also be coupled to any stepping or timing motors or manual drives. . . (335) Integral sensitivity adjustment allows detecting glass diodes or translucent sheets of

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2 Channel DYNOGRAPH
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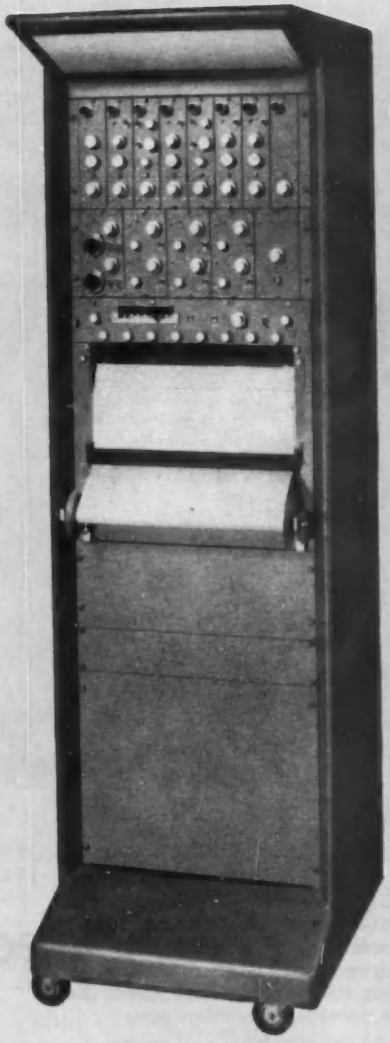
RP TWO CHANNEL
Compact, economical, convenient where only one or two channels are desired.

BMM/B CONSOLE
Features horizontal paper travel. Available as Type R or RC.

R SIXTEEN CHANNEL
Assemblies with 16 channels. 24 inch paper permits up to 24 channels on one inch centers.

RC DESK-TYPE CONSOLE
Medium gain assembly for computer write-out, telemetering, applications with input signal above 10 millivolts.



Write on your company letterhead for Bulletin 891, a 20 page, 2 color brochure giving you complete specifications, application data, etc.

VERSATILITY of assemblies—select the mounting best suited for your use.

VERSATILITY of application—one set of amplifiers covers all uses, microvolt to volts dc or ac, strain gages, reluctance gages, etc.

VERSATILITY of writing media—use ink, heat, electric interchangeably on one assembly—select the one most suited for the application.

The Offner Type R Dynograph Assembly is unmatched for sensitivity, accuracy, versatility—we invite you to compare it with any other high speed direct writing oscillograph.

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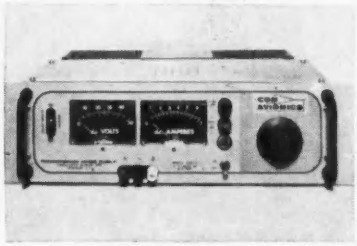
NEW PRODUCTS

paper with the PE-601 **photoelectric control** priced at $58 and available from **Syracuse Electronics Corp.**, Syracuse, N. Y. . . . (336) Gear ratios of 2 to 1 up to 400 to 1 may be selected with the **rotating cam limit switch** with built-in gear reducer being manufactured by **Gemco Electric Co.**, Detroit, Mich.

Circle No. 334, 335, or 336 on reply card

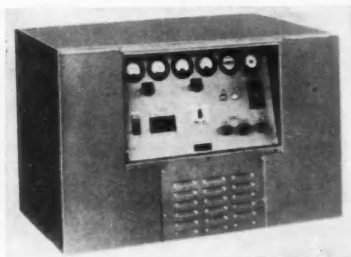
POWER SUPPLIES



HIGH CURRENT SUPPLY

Continuously variable dc voltage in the 0 to 50-volt range is the output of this series of transistorized wide range, high current power supplies. There are models in two series with maximum current ratings of 2, 5, 10, and 15 amp. Each series has regulation to either 0.1 or 0.01 percent. Units are said to be made to meet performance specs with even the worst combination of component characteristics. Test units have been short circuited 10,000 times without failure.—Consolidated Avionics Corp., Westbury, N. Y.

Circle No. 337 on reply card



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CIRCLE 237 ON READER SERVICE CARD

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Your Computer Designs

TO-5

NOW SMALLER
IN TO-18 CASE

RCA Adds To The 2N1301 Family

THREE NEW MESAS IN THE TO-18 CASE

- Minimum Betas of 30, 40, 50
- Typical G-BP* of 40, 60, 80 Mc.
- Pulse Repetition Rates Up to 10 Mc.

NEW IN TO-18 CASE: RCA 2N794, 2N795, 2N796. IN TO-5 CASE: RCA 2N1300, 2N1301, 2N1683

Once again RCA meets the stringent demands of the dynamic computer industry with new high-speed switching transistors specifically designed for today's military and industrial data processing applications. Here are some of the outstanding features of these high performance types:

- **High Power-Dissipation Capability**–150 mw (max.) at 25°C.
- **High Gain-Bandwidth Product***–40 (2N1300, 2N794), 60 (2N1301, 2N795), 80 (2N1683, 2N796). (Typical Values).
- **High Beta (h_{FE})**–30 min. (2N1300, 2N794), 40 min. (2N1301, 2N795), 50 min. (2N1683, 2N796).
- **Low Total Stored Charge In Saturating Circuits**–400 μμcoulombs (2N1300, 2N794), 325 μμcoulombs (2N1301, 2N795), 160 μμcoulombs (2N1683, 2N796). (Max. Values).
- **Rugged Mesa Structure**
- **Economy Performance**–Top Performance at Low Cost.

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1 SEQUENCE PROGRAMMER—T-297-1
Designed for Drone Applications
Operation.....4 output pulses at 28 vdc ±10%— sequence to order
Temperature.....—65°F to +165°F
Shock.....50 G's—11 msec.
Output.....2.0 amp. @ 28 vdc
Altitude.....>80,000 ft.
Power Consumption.....5 watts max.
Life.....>1,000,000 operations

2 BOOSTER RELEASE TIMER—T-249
Operation.....9.25 ±0.25 seconds
Temperature.....—65°F to +160°F
Shock.....50 G's 11 msec. any plane
Acceleration.....40 G's any plane (constant)
Contacts.....10 amp res, 5 amp ind.
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3 STATIC INVERTER—PS-105
Designed for Missile Application
Input.....28 vdc at 18 amps max.
Output.....no load—126 V rms 400 cps min. full load —115 V rms 400 cps max.
Load.....120 va max. on any phase, 300 va total
Efficiency.....>60% for full load
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Shock.....10 G's any axis—30 G's crash safety
Temperature.....—55°C to +71°C

4 COMPLEX INTERVALOMETER—T-270
Designed for A.S.W. Application
Operation.....8 individual delays
Time delay.....150 msec. ±0.50 sec.
Contact rating.....5 amp resistive
Voltage.....18 to 30 vdc
Weight.....3.5 lbs.

ES engineers welcome the opportunity to furnish an engineering estimate on your specific requirement. Emergency circumstances given special consideration. Ask for the AVIONICS DIVISION design folder.

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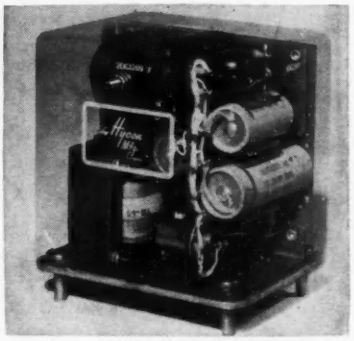
NEW PRODUCTS

range of substations. Basic centers consist of motor-alternators supplying 60 and 400-cycle three-phase, four-wire service and an alkaline battery pack supplying 24-28 vdc and equipped with a floating charger. Power ratings up to 55 kw are available. Static load voltage regulation is within 0.5 percent no load to full load; static line voltage regulation is to within ±0.25 percent for ±15 percent line variation.—Electric Specialty Co., Stamford, Conn.

Circle No. 338 on reply card



TWO LIGHTWEIGHT SUPPLIES

Designed originally for missile check-out equipment, both of these power supplies are transistor regulated. Model 322 weighs 1 lb, takes 115-volt, 400-cycle input and delivers 20 vdc, adjustable over a 10-percent range with an external potentiometer. Rated output current is 50 ma full load. Regulation is to better than 0.1 percent from full to 50 percent load. Short circuit protection is also provided. The Model 269, shown above, is similar in performance to Model 322 but weighs 4 lb and delivers 250 vdc at 250 ma. Regulation is to better than 0.4 percent from full to 50 percent load for a 20-percent line voltage change.—Hycon Mfg. Co., Pasadena, Calif.

Circle No. 339 on reply card

RANGE OF MODELS

Models 170 and 171 are regulated power supplies, each available in three physical configurations: a bench model, a plug-in model for chassis mounting, and a unit with terminal strip connections. Both models have outputs from 10 to 32 volts with regulation to better than 3 mv. Ripple is less than 250 microvolts rms. Performance characteristics of the two power

The Story in Back of a Symbol

Begin with a coil for perceiving electrical changes. Add two arrows and convert sensing ability into action. Now, enclose in an ohm ... and you have the signature of the REGOHM® family. These controls, of pure simplicity and reliability, are being used in over a million individual applications throughout the world.

Consider one fast-rising scion of the family tree—the REGOHM Transducer. If you would like to make a mosquito move a mountain, the transducer will bring you close to the summit. A few grams of force causing less than ⅛ inch movement effects direct control at the ¼ kw level.

Performance like this can significantly reduce costs in many control systems: Position, Tension, Weight, Loop, Speed, Pressure and others.

ERC Engineers are ready to assist you with your application. To learn more about the REGOHM Transducer, contact:

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NORWALK, CONNECTICUT
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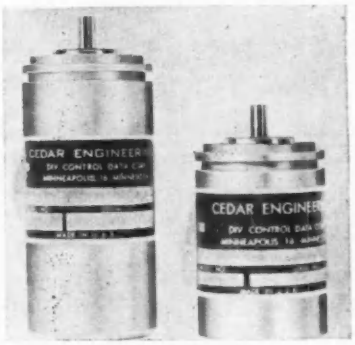
CIRCLE 238 ON READER SERVICE CARD

supplies are similar, except the 171 has an output current of 0.50 amps and the 170 an output current of 0.25 amps. Both feature overload and short circuit protection. Prices: Model 170, $98, Model 171, $123.—Quan-Tech Laboratories, Inc., Boonton, N. J.

Circle No. 340 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



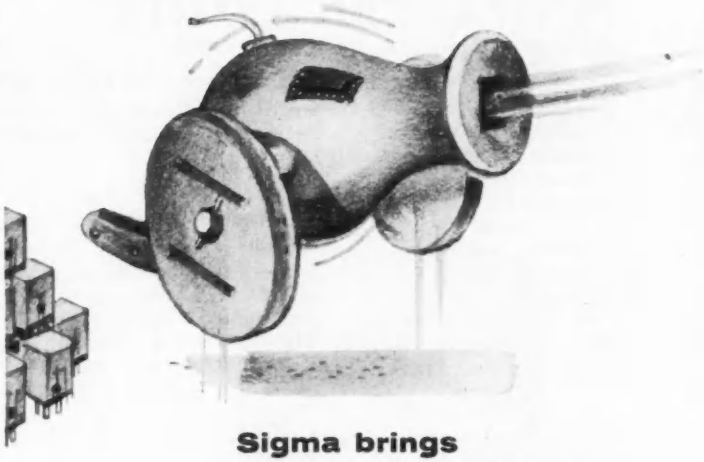
SHORTENED MOTORS

Shown above is the size comparison of a standard servomotor-tach and a new shorter model. Available now in Sizes 8, 10, and 11 as servomotors and servomotor-tachs, the shorter devices are also to be produced in other sizes. The Size 10 motor-tach shown above is reduced from 2 in. to 1.375 in. long, but still retains the conventional model's performance characteristics. In fact, the shorter length minimizes susceptibility to vibration failure, and electrical efficiency is increased since the technique which produces the shorter over-all length also allows normal motor output at lower power input. Quantity price: about $60.—Cedar Engineering, Div. of Control Data Corp., Minneapolis, Minn.

Circle No. 341 on reply card

LOW POWER MOTORS

Designed with ball bearings, these miniature motors can be built for dc operation as shunt-series or split field motors or ac series-type universal motors. At 8,000 rpm the dc version of



Sigma brings big gun to bear on commercial relay field

There's a new Sigma relay just coming into the picture that's so disarmingly simple in design, construction and operation that Believers in Complexity will probably get mad when they see it. (After all, if you give someone a simple answer to anything nowadays they think that you couldn't possibly have understood the problem.) But the reaction around here is that the designer's really got something, and there was even talk about erecting a small monument to him in the parking lot.*

We were going to call this new general purpose AC-DC relay the "Series 90" until there was some rumbling in the number department, so now it has the much more economical, sensibly conservative number of 46. It's an honest-to-goodness *good* heavy duty commercial relay, that will switch up to 10 amp, 120-volt resistive loads on as little as 200 mw. DC or 0.5 v-a AC. What the big simplicity pitch Means To You is that there are so few parts it's almost impossible for anything to get out of whack; the few parts it *does* have aren't hard to make or assemble (translated, $3 or $4 per relay in quantity); a big motor and fat DPDT contacts efficiently use every bit of the volume and give a long mechanical life — from 500,000 operations on 10 amp loads to 10 million operations at no load. Since we hope the "46" will find its way into such things as machine tool controls, timers and laundry equipment (and even smarter Electronic Devices as well), the octal plug-in base has the same pin connections as the relays already sitting in this type of equipment. If you want to call this a retrofit, go right ahead. That's it there in the picture, in a revealing 1 5/16" x 1 5/16" x 2 1/16" plastic enclosure.

The first few thousand are now beginning to roll, and while we're not quite ready to talk delivery by the carload, anyone interested in trying out 46's in sample quantities will get to sit in the sales manager's padded office for 8½ glorious minutes.

*We decided not to overdo it and gave him a Rolls-Royce instead.

Series 46 Relays and other selected Sigma products and personnel on display at booths 2628-2630, New York Coliseum, March 20 to 23. Come energize them.

SIGMA

SIGMA INSTRUMENTS, INC.
69 Pearl Street, So. Braintree 85, Mass.

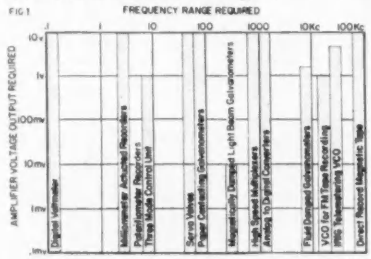
CIRCLE 187 ON READER SERVICE CARD

D-C AMPLIFIER EVALUATION *number 4 in a series*

AMPLIFIER GAIN

The voltage amplification or gain of a d-c amplifier is the dimensionless ratio of the output voltage to the input voltage, assuming operation in the linear portion of the amplification characteristic, and at a specified frequency, usually 0 cps. The curve of amplifier gain vs. frequency of the input signal is termed "frequency response".

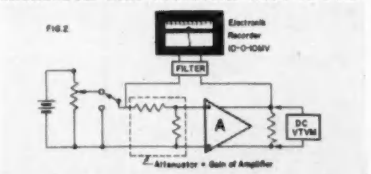
The gain factor is of little value to the user unless the minimum full scale input or the maximum linear full scale output is known. As part of a system, the desired amplifier output level is determined by the load characteristics. Typical amplifier loads are shown in Fig. 1.



If the output requirement is known, the gain needed to amplify the input to give full scale output can be determined. However, power requirements must also be considered. If the load resistance is sufficiently low the maximum output current is reached before maximum voltage output, and the amplifier will saturate with further increases in input signal. The value of the voltage across the load with maximum rated current is then used to determine gain.

Gain Stability vs. Gain Accuracy

The errors in gain caused by external factors such as ambient temperature, line voltage, and component aging are termed gain instability. Gain accuracy is the allowable tolerance between gain settings and actual gain. Gain instability may be measured and recorded with a null



comparator circuit as shown in Fig. 2. The gain accuracy may be determined by substituting in this circuit a precision attenuator. For information on gain stability measurement write for application notes BEAN 122.

AccuData III has Gain of 34,000

Full scale output of the new Honeywell AccuData III d-c amplifier is 10 volts to 20 kc, or 50 ma to 10 kc. Minimum full scale input is 0.3 mv single-ended, a voltage gain of 34,000. Its gain instability is ± 0.01% for a ± 10° F. temperature range. Gain setting accuracy with the fine gain control in the CCW position is ± 0.2% for differential or single-ended connected gains up to 1000, and ± 0.5% for

gains in the 3000 to 34,000 range. Eleven different gain positions including zero and an open loop position for operational amplifier connections are provided. Other features of this amplifier include high common-mode rejection, very low noise and drift, and unparalleled linearity. Write for Bulletin BS DISA-3 to Minneapolis-Honeywell, Boston Division, Dept. 3, 40 Life Street, Boston 35, Massachusetts.

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Honeywell

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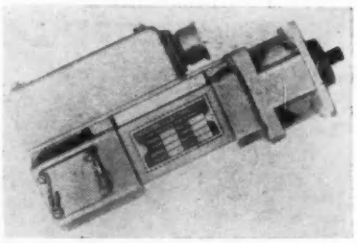
SINCE 1885

NEW PRODUCTS

these motors develops 1/100 hp; ac version develops 1/200 hp. Output ranges from 6 to 115 volts. These continuous or intermittent duty motors, the DS-105 group, are 2.562 in. long, plus a standard 1-in. shaft. Other shaft lengths are available. OD of the motor housing is 1.678 in., and motor weight is 11 oz.—Heinz Mueller Engineering Co., Chicago, Ill.

Circle No. 342 on reply card



SHORT STOPPER

The Model 2030 is a lightweight, square frame dc motor designed for applications where short stopping time and high holding torque in the power off condition are required. A self-contained electromagnetic clutch-brake allows the low cost and irreversibility with no power. For continuous duty the motor is rated at 0.33 hp at 14,000 rpm; intermittent duty, 0.62 hp at 8,750 rpm. Device operates on 26 vdc and measures 7.48 in. long by 2.44 in. square; weight is 4.7 lb including a radio noise filter. Efficiency is 45 percent. Other models using the same frame are available from 1/20 to 1 hp with speed ranging to 35,000 rpm. —Hoover Electric Co., Los Angeles, Calif.

Circle No. 343 on reply card

COMPONENT PARTS

9,000 BITS PER CHANNEL

Now available for process or machine control systems, this magnetic drum delay/memory system is designed for low initial investment with flexible add-on features. Basic part of the system is a magnetic oxide drum with storage densities up to 9,000 discrete information bits per channel. Recording heads adjust to provide variable

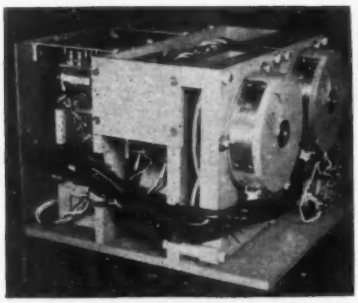
delays of 2-60 sec. The console contains the drum, drum drive, power supply, record and playback heads, permanent magnet erase head, and panel mounted record and playback amplifiers. Output is digital in the form of on-off pneumatic, hydraulic, or electrical control signals. Power requirement is 110 volts, 60 cycles.—Electron-Ohio, Inc., Solon, Ohio.

Circle No. 344 on reply card

RECENTERS SHAFTS

The Series 1300 is a recentering mechanism designed to return to center the shafts of components like synchros, potentiometers, encoders, commutator switches, and gear trains. Available in sleeve or ball bearing versions, the units come either with standard servo mounts or with mounting designed for inclusion in original design configurations. Stops are adjustable up to 320 deg. Prices range from $30 to $80.—MagneTec Corp., Canoga Park, Calif.

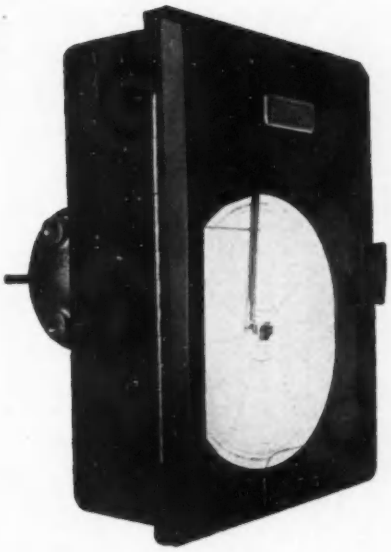
Circle No. 345 on reply card



TWO-SPEED REPEATER

Used with appropriate synchro-transmitters, this two-speed servo repeater system provides digital coded contact closures corresponding to angular position of a remote shaft. An integral package, the device contains two control transformers, a servomotor, a synchro-switch, a servoamplifier, two shaft position encoders, and interconnecting gear trains. Output is suitable for entry through storage and translation circuitry to recording devices like

THE FLOW RECORDER YOU CAN COUNT ON



Absolute dependability, under the most demanding operating environments—that's the promise and the performance of the Barton 202A flow recorder. Thoroughly proven in the gas production fields, the 202A is enjoying ever-increasing popularity in gas transmission and distribution systems. It is compact and ruggedly built, not subject to the usual frailties of such a precise instrument; it has built-in overrange protection, which allows it to maintain calibration under wide pressure fluctuations; it is immune to condensate problems, making it ideal for application in all geographical areas. A recently added bonus: the 202A can be fitted with the new Barton chart changer which allows the instrument to record continuously and unattended, for up to 16 days, using a fresh chart each day. For complete information and specifications on the 202A flow recorder, request Bulletin 202A-1.

BARTON

RECORDER-INTEGRATORS/CONTROLLERS/DIFFERENTIAL PRESSURE INDICATORS/PNEUMATIC TRANSMITTERS/FLOW SWITCHES

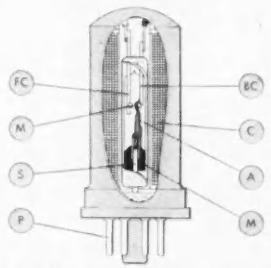
BARTON INSTRUMENT CORPORATION • MONTEREY PARK, CALIFORNIA

CIRCLE 189 ON READER SERVICE CARD 189

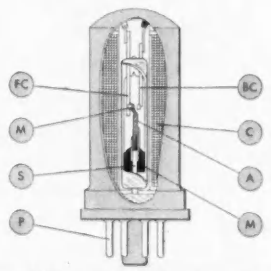
100 OPERATIONS PER SECOND! 100 POSITIVE

New Adlake mercury wetted contact relays* deliver billions of trouble-free operations at speeds up to 100 operations per second. Ideal for applications as computing systems, signaling devices, tabulating machines and high speed switching. Thanks to mercury contact, they enjoy low, constant contact resistance, never become dirty or pitted, will not respond to the mechanical vibration of the metal armature. Will always provide positive closure. Contact rating is 250 volt—amperes, 500 volts maximum. 5 amperes maximum (with suitable contact protection.)

Manufactured under license agreement with Western Electric Co., Inc.



Platinum butterfly contact at top end of swinger or armature A rests against the normally closed contacts BC completing circuit. This electrical circuit is closed through mercury M adhering to platinum swinger contact point and also mercury adhering to platinum contacts at end of normally closed contacts BC. Circuit is further connected to proper pins P to complete circuit inside enclosure with external connections.



When coil C is energized, swinger moves from the normally closed contacts BC to the normally open contacts FC. This opens the normally closed circuit and closes the electrical circuit through the normally open contacts, FC through stem S, and through proper pins P to external circuit. Mercury M from pool at bottom of switch replenishes mercury dropped after each operation from contact points so circuit is always made and broken through two mercury surfaces.

A+ Adlake® mercury-wetted relays

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Relay Division, Elkhart, Indiana

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company

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city & state

NEW PRODUCTS

printers, tape and card punches, and lamp banks. The encoders may contain up to 1,024 bits in various codes per 360-deg rotation.—Datex Corp., Monrovia, Calif.

Circle No. 346 on reply card

PLUS . . .

(347) New from **U. S. Electrical Motors, Inc.**, Los Angeles, Calif., is a Synchrogear **speed reducer** with an improved gear arrangement that allows low speed, high torque, extra capacity performance . . . (348) A miniature precision **mechanical differential** made available by **Bowmar Instrument Corp.**, Ft. Wayne, Ind., is designed for loads up to 75 oz-in. and speeds to 3,500 rpm. . . . (349) **Harvey Wells Electronics, Inc.**, Natick, Mass., has placed on the market an addition to its logical building block line, a dual output **variable delay module.**

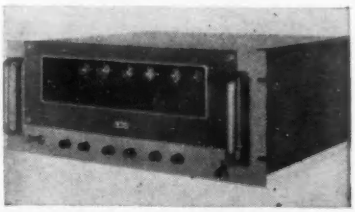
Circle No. 347, 348, or 349 on reply card

ACCESSORIES & MATERIALS

LINKS COMPUTERS

Off-the-shelf equipment for linking analog and digital computers is now available, a step ahead of the custom engineered systems previously needed for this combination. Two standard systems have been developed for linking commercially available analog computers to IBM 700-7000 series, Bendix G-15, or the manufacturer's own PB 250 digital computers. Price: about $38,000.—Packard Bell Computer, Div. of Packard Bell Electronics, Los Angeles, Calif.

Circle No. 350 on reply card

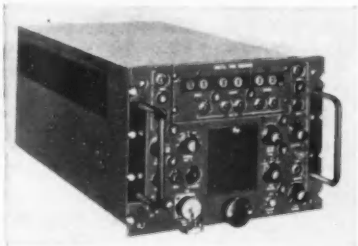


ACCURATE GENERATOR

An accuracy to within 0.005 percent is claimed for this all-electronic digital

time generator for system control and synchronization or for time correlation among diverse data acquisition and logging devices. Unit uses a 1-kc tuning-fork oscillator to achieve this accuracy. Two sets of outputs are delivered: oscillator provides 0.001-sec interval markers and markers at 0.01, 0.1, and 1 sec by means of transistorized flip-flop dividers. Decimal outputs to a total of 23 hr, 59 min, 59 sec are provided at a connector and are displayed on six glow-tube indicators. An optional output set can be provided to yield bcd signals. Price: $2,950.—Information Technology Div., Lockheed Electronics Co., Metuchen, N.J.

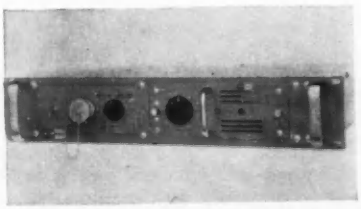
Circle No. 351 on reply card



CORRELATES TIME

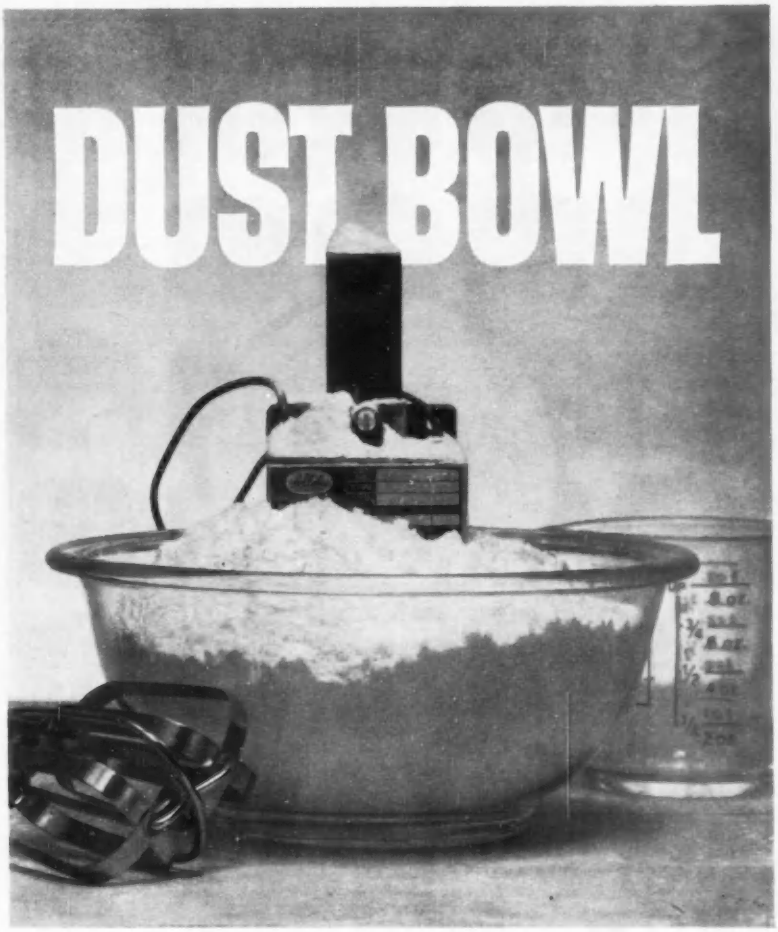
Time of simultaneous recording processes at up to 10 or more separate locations can be correlated to within ± 1 sec per day using this new electronic timing set. Basic unit is a self-contained pulse generator, binary-decimal time encoder, and 24-hr numerical block. Up to 10 remote time indicators can be controlled while composite binary coded time signals and timing marker pulse trains are provided. The set is compatible with any analog, digital, or analog-digital instrumentation or data processing system requiring real or relative time correlation.—The Hallicrafters Co., Chicago, Ill.

Circle No. 352 on reply card



EXTENDS VOLTMETER RANGE

The floating, narrow band differential dc preamplifier shown above is capable of extending the range of digital voltmeters to 1 microvolt dc. It provides stable accurate amplification of low level signals in the presence of high common mode noise and hum. Common mode rejection is 180 db for dc



An Adlake mercury displacement relay functions perfectly — even smothered in dust, dirt, powder or flour. Neither gas nor organic material can penetrate its seal. Inside, mercury-to-mercury contact takes place in a pure, non-oxidizing atmosphere. This liquid contact completely eliminates failures caused by low contact pressure, contact burning, pitting and sticking. Provides a new and clean contacting surface for each operation. Small reason Adlake relays stand up in "dirty situations" where mechanical relays clog and fail.

MAIL COUPON FOR CATALOG OF MERCURY DISPLACEMENT RELAYS

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MERCURY DISPLACEMENT RELAYS

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Relay Div., Elkhart, Indiana

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CIRCLE 191 ON READER SERVICE CARD

NOW . . .

Metal Film Potentiometers

Here is a new addition to MECHATROL'S product line of precision rotating components . . . . . METAL FILM POTENTIOMETERS.

Using a unique new process, MECHATROL manufactures the deposited film potentiometer resistance element in a high vacuum chamber using electron bombardment techniques. This provides a thin film metallic resistance element of extremely fine granularity capable of being resolved into infinitely small changes in resistance. Resolution is better than 0.01%.

MECHATROL'S thin film potentiometer exhibits superior wear and rotational life under conditions of high ambient temperature and severe vibration and shock. Standard units measure 1-1/16 inches in diameter and are available for servo or panel mounted applications. Special units designed and manufactured to meet your exact specification.

FEATURES:
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Temperature . . −55°C to +125°C
Vibration . . . 10 g's, 10-2000 cps.
Rotational Life . . 1,000,000 cycles

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and 130 db for 60 cps with up to 1,000 ohms unbalance in either signal lead. Fixed gains of −10, −30, −100, −300, and −1,000 are selectable. Input can be floated up to ±250 vdc or peak ac. Price: $1,475.–Kin Tel Div. of Cohu Electronics, Inc., San Diego, Calif.

Circle No. 353 on reply card

CLEAR POTTER

A new clear silicone potting and embedding compound that protects electronic parts both mechanically and dielectrically has been made available. The low temperature vulcanizing (LTV) compound cures at 70-80 deg C in 16 hr to a flexible, resilient solid. In 1-lb quantities the LTV 602 sells for $10.50 a lb.–Silicone Products Dept., General Electric Co., Waterford, N.Y.

Circle No. 354 on reply card

MORSE CODE GENERATOR

A portable manual entry code generator named Codamite is designed to produce Morse characters, but binary coded decimal characters can be provided. The 4-lb unit has a transmission speed varying from 6 to 42 words per min. The 43-character keyboard includes numbers, letters, and punctuation. Rechargeable nickel-cadmium batteries allow 5 hr of continuous operation. A recharging plug is included with the Codamite. The generator is suitable for manual entry into data processing and telemetry systems. Price: $1,275.–Ling-Temco Electronics, Inc., Anaheim, Calif.

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3-SEC DEVELOPING

This new photo recording paper needs only a 3-sec exposure to heat for development. A visible image forms on the paper in 1½ sec. Expected to be used extensively with oscillograph recording, this new silver sensitized paper has chemicals for development incorporated in the photographic emulsion. Called K-1549, the paper is fast enough for exposure in oscillograph recorders with high intensity mercury lamps. Oscillograms remain readable for months.—Eastman Kodak Co., Rochester, N.Y.

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New Products

350—Analog-digital computer link, p. 190
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Bulletins and Catalogs

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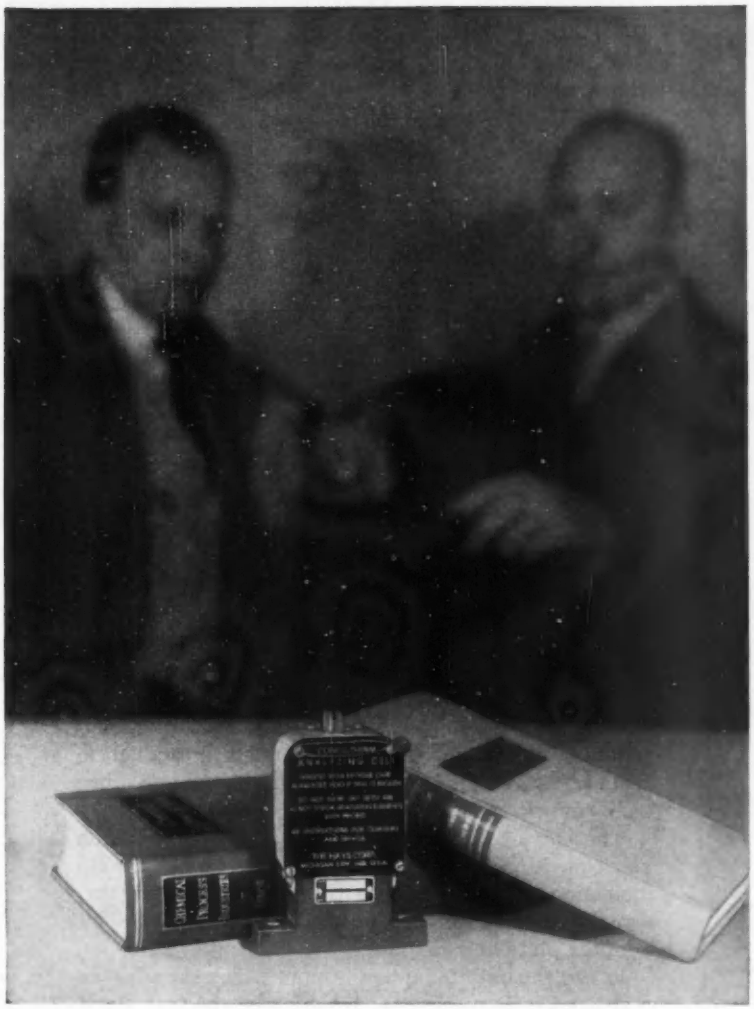
• • •

World's largest private telephone system has been installed by Lockheed Aircraft Corp. to link 65 offices and facilities across the U.S. Using 100,000 miles of lines leased from 15 telephone companies, the net, besides providing dial service between 21,727 telephones, will increase the flexibility of LAC's four main EDP centers.



"continuous analysis of almost any gas?"

"Yep . . . at a fifth the cost of a Chromatograph"

That's the analyzing cell of the standard Hays Thermal Conductivity Analyzer, proven in over ten years of successful experience with many gases. This Analyzer is rugged, dependable . . . gives a continuous record, not just periodic samplings. With the Hays Universal Recorder . . . and one of the wide selection of Hays sampling systems tailor-made for your application . . . it solves almost any gas analysis problem.

for further details write for bulletin B641

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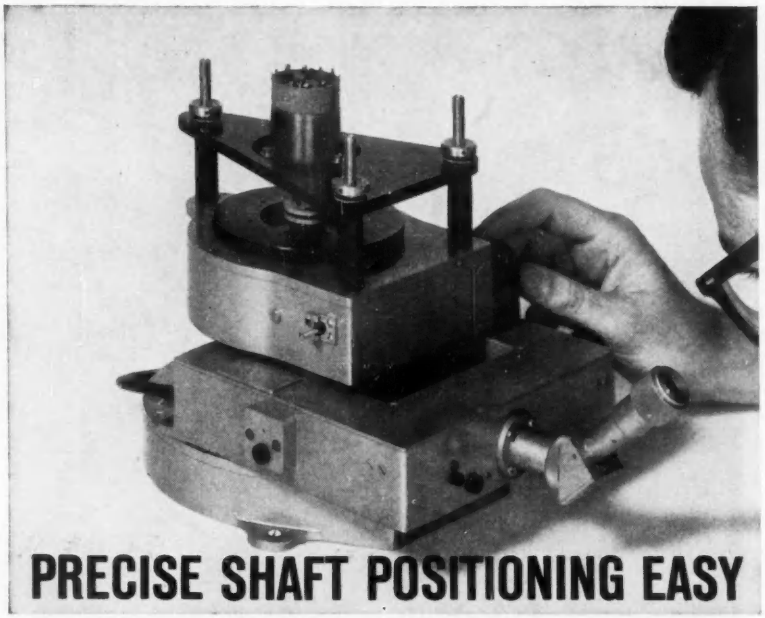


PRECISE SHAFT POSITIONING EASY

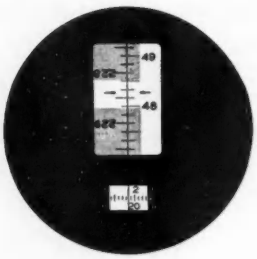
WITH GURLEY RESOLVER TEST STAND

The new Gurley Resolver Test Stand solves the long-standing need for a reliable instrument in production tests of resolvers, synchros, potentiometers and other such equipment.

The Gurley Model 7530 test stand is a precision shaft-positioning device, consisting of an optical coincidence reading system with ± 2 second accuracy, a rack and gear for precise shaft positioning, and an adaptor plate and coupling.

In use, the unit under test is mounted on the adaptor plate and is connected to the shaft of the test stand by a miniature flexible coupling. The shaft system is then quickly adjusted to an approximate angular position by means of the rapid drive disc. Accurate final positioning is accomplished with a slow motion drive. The angular position of the shaft is read directly to the nearest second of arc.

For an illustrated bulletin, write on your letterhead to Industrial Division, W. & L. E. Gurley, 537 Fulton Street, Troy, N. Y.



W. & L. E. GURLEY

TROY, N. Y.

BULLETINS AND CATALOGS

NOTE: First three items require direct written requests and remittances. Complete addresses are given for these.

MEASUREMENT HANDBOOK. General Radio Co., West Concord, Mass. "Handbook of Noise Measurement", 100 pp. Offers a complete survey of topics like man as a noise-measuring instrument, applications of sound-measurement systems, noise source characteristics, and noise control. Four appendices contain decibel conversion tables, vibration charts, definitions, and references. Price $1.

ROTAMETER STANDARD. Instrument Society of America, Technical Publications Dept., 313 Sixth Ave., Pittsburgh 22, Pa. Recommended Practice ISA-RP16.4. Developed by the society's Standards and Practice Dept., the tentative practice provides a basis to define the nomenclature and terminology for extension-type variable area meters (rotameters). Price: $0.50 (ISA members), $0.75 (nonmembers).

GAS VALVE STANDARD. National Electrical Manufacturers Association, 155 E. 44th St., New York 17, N. Y. "Automatic Gas Valves", DC 8-1960. New publication covers definitions, dimensions, and capacities of automatic gas valves and devotes space also to the combinations of functions, capacities, and over-all dimensions of combination automatic gas valves. Price: $0.30.

(400) FULL RELAY LINE. Potter & Brumfield, Div. of American Machine & Foundry Co. Catalog, 16 pp. Manufacturers' complete line of electromagnetic relays is covered in a new two-color catalog that includes comprehensive data on 42 different series of relays. Most information is presented in chart form for quick comparison. Mounting data and enclosure description, as well as terminal information, are featured.

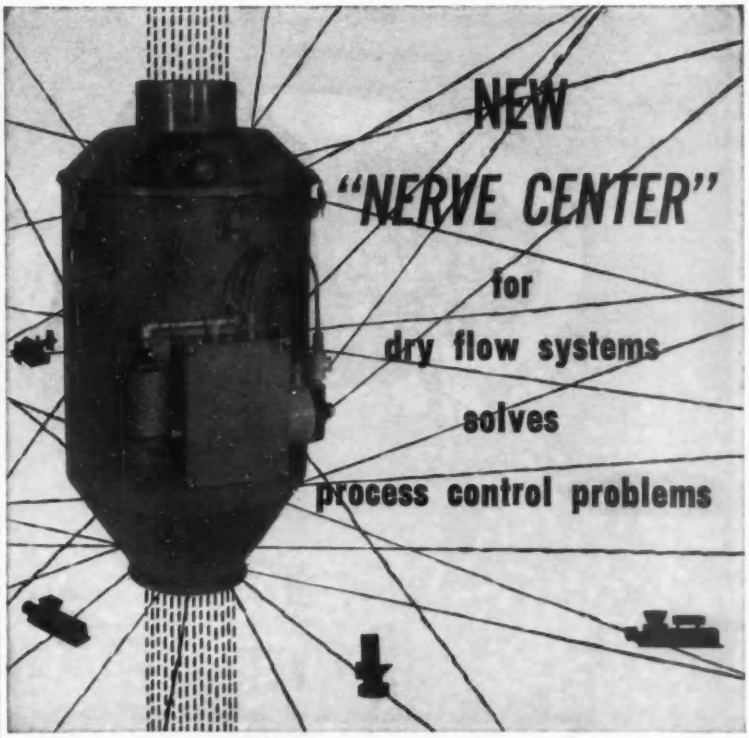
(401) ANALYSIS SYSTEMS. Minneapolis-Honeywell Regulator Co., Industrial Systems Div. Brochure DB 9075, 16 pp. Two automatic wave analysis systems, a cross spectral analyzer, and a two-channel analyzer for transfer function plotting are described in this new colorful publication. Included are complete specifications, charts, formulas, and equipment options.

(402) MICR QUESTIONS AND ANSWERS. A. B. Dick Co., Booklet, 48 pp. Check-shaped publication uses many clear illustrations and useful two-color layout to answer 142 most frequently asked questions about magnetic ink check encoding. ABA spec, requirements and costs of imprinting, quality control are among topics covered.

(403) MOISTURE AND DENSITY CONTROL. Nuclear-Chicago Corp., Industrial Div. Brochure, 8 pp. Describes the Qualicon systems line for continuous measurement and control of moisture and density of materials on conveyors in pipes, bins, hoppers, tanks, mixers, and blenders. Included are bulk density, liquid density, bulk moisture, and fluid moisture gages.

(404) COMPLETE MOTOR LINE. The Louis Allis Co. Bulletin 2651, 8 pp. Includes photographs and descriptions of 23 types of motors for a broad range of applications. Listed are squirrel cage motors,

gear motors, dc motors to 400 hp, alternators, and immersible motors, among others.
(405) MACHINERY CONTROL SYSTEMS. Bendix Corp., Industrial Controls Section. Catalog 308, 16 pp. Covers DynaPath contouring controls and Dyna-Point and Ferranti positioning controls, along with the Ferranti coordinate measuring machine. Numerical control system accessories are also described with complete specifications given for all units, as well as features and application data.
(406) BOILER CONTROL. Babcock & Wilcox Co. Bulletin G-101, 8 pp. Colorfully illustrated study of the current status and future of computing-control for boilers. Topics covered include benefits of computer control, methods of programming, control approaches, flame dimension and burner control, and operation simulation.
(407) GEARS AND MOUNTINGS. Perfect Gear and Instrument Corp. Catalog 5A, 128 pp. Pocket-sized catalog covers line of stock precision I, II, and III gears and instrument clamps. Complete diagrams, dimensions, specifications, and prices are included for rapid selection.
(408) SHORTENED 'SCOPE CATALOG. Tektronix, Inc. Abridged catalog, 16 pp. Short form publication describes all of the manufacturer's current oscilloscopes and associated equipment. A total of 42 various types of 'scopes and more than a score of accessory equipments are described with photographs and specs.
(409) MAGNETIC CONVEYOR CONTROL. Electronic Controls Div. of Flo-Tronics, Inc. Bulletin MP50-6011, 6 pp. Describes operation of the Mag-Pac magnetic system for conveyor control of packages, parts, or containers. Details the principal units in the systems: dispatcher, marker, tally, reader, and coordinator.
(410) O-RING GUIDE. Advance Products Co. Slide rule chart gives proper installation dimensions for plain, plated, and coated O-rings from ¼ to 50 in. in diam. All that is needed is desired nominal outside diameter for any standard ring. Chart also shows how to calculate dimensions for nonstandard rings.
(411) PORTABLE COMPUTER. Donner Scientific Co., Sub. of Systron-Donner Corp. Brochure, 6 pp. Describes Model 3500 portable analog computer, designed to study any physical system that can be described by differential equations. Literature details ease of use, accessories available, and typical applications.
(412) TRANSDUCER DATA. Standard Controls, Inc. Data folder, 12 pp. Data package includes 4-page synopsis of pressure transducer definitions which make easier reference to the four 2-page data sheets describing the SP-2 Series of pressure transducers. Data sheets include specifications and circuit diagrams.
(413) HEAVY DUTY SWITCHES. Unimax Switch Div., The W. L. Maxson Corp. Catalog 30-1, 16 pp. Furnishes complete details on horsepower rated series of metal-cased switches and a double break type of switch. Photographs, specifications, and dimension drawings are given for each model, and a page of hints for applying limit switches is included.
(414) TERMINOLOGY CLARIFIER. Scientific and Process Instruments Div., Beckman Instruments, Inc. Application



The new W&T Massometer® senses flow in closed systems. It measures dry, free-flowing materials and translates the results into a 3-15 psi signal. The unit can be used to indicate or record. It also controls proportional blending . . . helps solve problems in all kinds of control situations.

And the Massometer does all this without breaks in your closed system. Air-tight construction means a flow-sensing unit that seals dust in . . . seals contamination out. It is compact and easily installed, fits neatly into the line. Stainless steel for parts exposed to the flow stream and dust-tight motor casing assure years of maintenance-free service.

The Massometer is calibrated with any maximum output between 40 and 200 lbs. per minute. Maximum volumetric capacity is 6 cubic feet per minute. Repeatability within ±0.2% of full scale assures stable performance.

By generating a signal proportional to flow, the W&T Massometer brings a new look to ratio control. Its versatility means more accurate batch processing, or helps create continuous processing in new or existing systems.

For information, write Dept. M-50.28.

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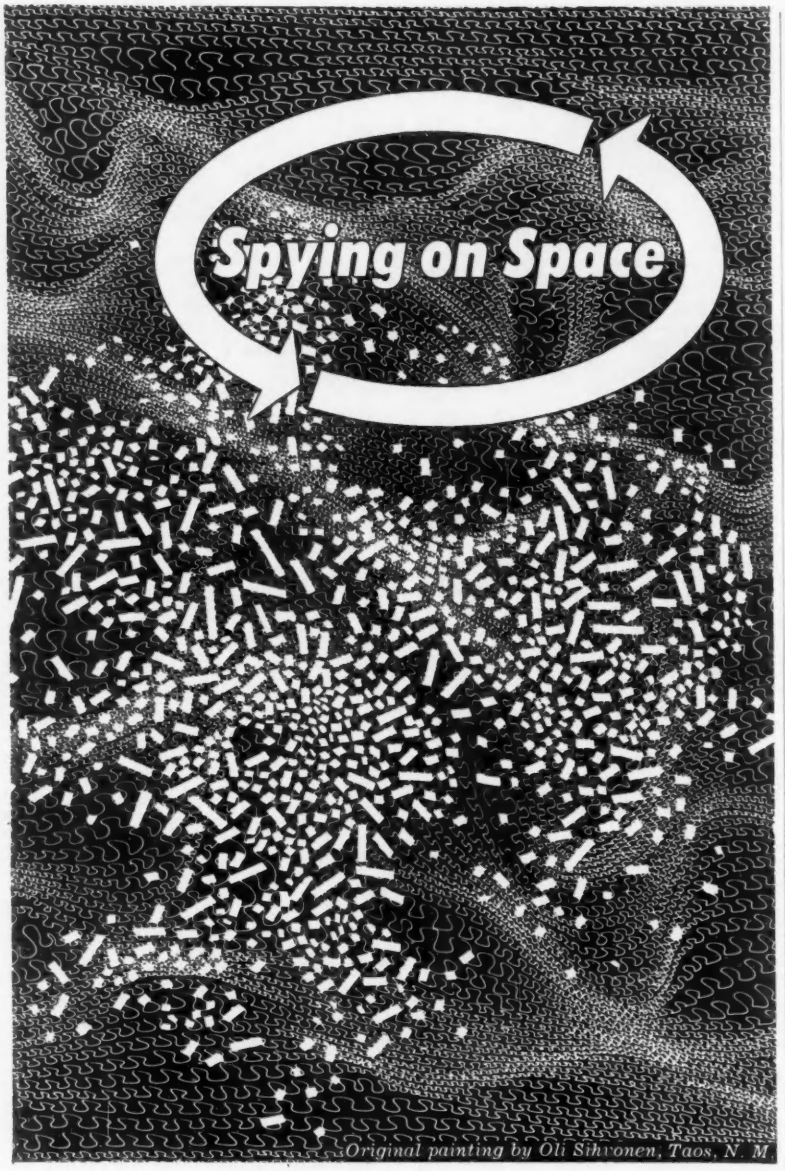


Original painting by Oli Sihvonen, Taos, N. M.

Through the use of tissue equivalent dose rate meters carried on various high altitude research rockets, Los Alamos scientists are learning much about radiation in space, including its possible effect on humans. The instruments simulate human tissue, observe the effects of radiation and telemeter the data back to earth.

For Employment Information Write:
Director of Personnel Division 61-24

los alamos
scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

data sheet P-8072, 2 pp. Aimed at clearing up the ambiguity surrounding the term "density", the sheets sets up standard terms to differentiate between types of density and types of porosity. It also spells out the capabilities of the manufacturer's Pycnometer to measure volume density and porosity.

(415) ZENER DIODE TYPES. Dickson Electronics Corp. Data sheets, 16 pp. Four 4-page sheets spell out technical data of a line of zener diodes that includes ¾, 1, 1½, and 10-watt types. Included are electrical characteristics in tabular and graph form along with dimension drawings.

(416) GAS CHROMATOGRAPH. Scientific and Process Instruments Div., Beckman Instruments, Inc. Bulletin 787, 14 pp. Describes the GC-2A analytical gas chromatograph by spelling out operating principles and application techniques. Well illustrated brochure includes typical chromatograms. Also described are chromatograph accessories.

(417) TRANSDUCER DESIGN APPROACH. Electric Regulator Corp. Booklet. Entitled "Mechanical to Electrical Transducer", this description of the Regohm transducer summarizes the design approach of this control component. Photos and drawings illustrate applications, operating principles, and design considerations. A cutaway illustration shows how a wide operating spectrum is attained.

(418) DETAILED POTENTIOMETER RUNDOWN. Electronic Sales Div., De-Jur-Amsco Corp. Catalog 1160, 28 pp. Technical catalog on complete line of precision potentiometers includes detailed specifications, outline drawings, photographs, and general information on units from ½ to 5 in. diam. Types include ganging, high resolution, and sine-cosine pots.

(419) THYRATRON USE GUIDE. CBS Electronics Div., Columbia Broadcasting System, Inc. Bulletin PA-503, Vol. 3, No. 4 of "Tech Tips", 4 pp. Covers the care and control of thyratrons. Included are how they are controlled, what their ratings mean, and a few applications.

(420) VALVE SIZING CHARTS. OPW-Jordan Corp. Bulletin JSC-1, 4 pp. Simplified charts tell how to size sliding gate regulators and control valves for steam, liquid, and gas service. Cross reference compiling eliminates need for rulers, formulas or slide rules. Data show how to adjust sizing for pressure, temperature, viscosity, or specific gravity variations in any valves, regardless of make.

(421) EDP HUMIDIFICATION. Walton Laboratories, Inc. Bulletin, 2 pp. Describes need for humidity control in data processing installations to control the computers' accuracy. Computation for a typical humidification equipment installation is included.

(422) SWITCHING TRANSISTOR GUIDE. Philco Corp., Lansdale Div. Booklet. Designed to aid engineers in selecting proper transistors for applications like saturated DCTL, SCTL, RTL, RCTL, and DTL low level logic circuits. Also in-

cluded are nonsaturated logic switching descriptions. Schematics, curves, and charts show appropriate design and use of inverters and flip-flops in switching circuitry.

(423) ELECTRONIC MONITOR. Lynch Communications Systems, Inc. Booklet B1020-SB-1, 8 pp. Describes high speed continuous electronic monitoring systems which can monitor any condition representable by a contact closure. Photos and block diagrams supplement general description, and glossary and technical specifications are included.

(424) SPECTRUM ANALYZER ARTICLE. General Applied Science Laboratories, Inc. Form SA11-6011-2, 8 pp. Technical article by company engineers describes very low frequency spectrum analyzer that operates in the range of 0.0025 to 1,000 cps on a real-time basis. Block diagrams and frequency plots highlight the text. Also included is a 4-page data sheet.

(425) AUTOMATIC COMPUTER PROGRAMMING. Bendix Computer Div., Bendix Corp. Bulletin AR-1060, 8 pp. Describes several of the automatic programming systems for the manufacturer's G-15 digital computer. General characteristics of the systems for commercial and scientific applications are included along with partially coded problem illustrations.

(426) RECTIFIER DATA SHEETS. General Electric Co., Semiconductor Products Dept. Specification sheets 170.20, 160.20, 160.21, 4 pp. each. Representing new or revised versions of specifications for three models of silicon controlled rectifiers, these sheets include complete characteristic curves, outline drawings, and an informative list of symbols and definitions.

(427) MAGNETIC ALARM UNIT. San Diego Scientific Corp. Brochure, 4 pp. Describes new solid state alarm device for monitoring thermocouple, resistance thermometer, and strain gage inputs. Bistable magnetic amplifier is the only active element. Publication includes block diagrams of the alarm and control modules.

(428) UNIVERSAL CHECKER. Audiotronics Co. Bulletin, 8 pp. Describes Speed-Tronic automatic checkout system that can check any characteristic convertible to an electrical signal. Photographs, block diagrams, and detailed specifications supplement the text.

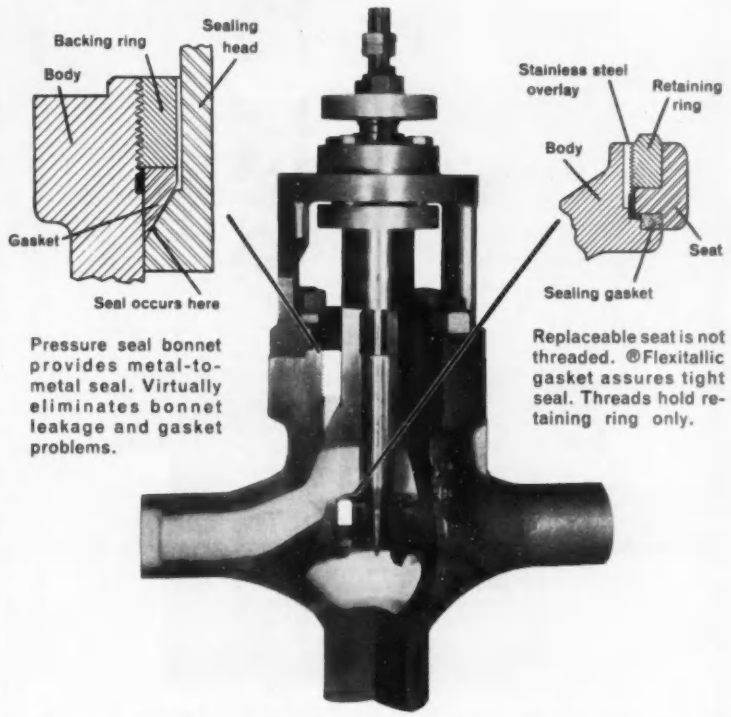
(429) COMBUSTION CONTROLS. Reliance Instrument Div., Electro-Mech Corp. Bulletin 1001, 32 pp. Guide covers the design and selection of combustion control systems including a clear analysis of both proportioning and metering types. Block diagrams are used to point out the advantages for specific applications.

(430) SHAFT ENCODER TRANSLATION. Harvey-Wells Electronics, Inc. Brochure, 8 pp. Describes in detail the operation of two shaft encoder translators for maximum and for slow speeds. Logic block and timing diagrams supplement the comprehensive technical description.

(431) MICROWAVE COMPONENTS. Microlab. Catalog No. 10, 72 pp. Detailed descriptions and specifications along with illustrations are given for a line of coaxial components. General technical information to assist in component selection is included as is an article on the use of matrix algebra in network design.

ROCKWELL-REPUBLIC

High pressure globe valve withstands pressure drops up to body ratings



Pressure seal bonnet provides metal-to-metal seal. Virtually eliminates bonnet leakage and gasket problems.

Replaceable seat is not threaded. ®Flexitallic gasket assures tight seal. Threads hold retaining ring only.

Rockwell-Republic high pressure globe valves are available in 1½", 2", and 3" sizes for 1500, 2500 and 4500 psi standards. In addition to removable seat and pressure seal bonnet, these valves are available with bolted bonnets and quick-change trim. For more information about this and other Rockwell-Republic components and systems, just mail the coupon below. RF-23

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ROCKWELL

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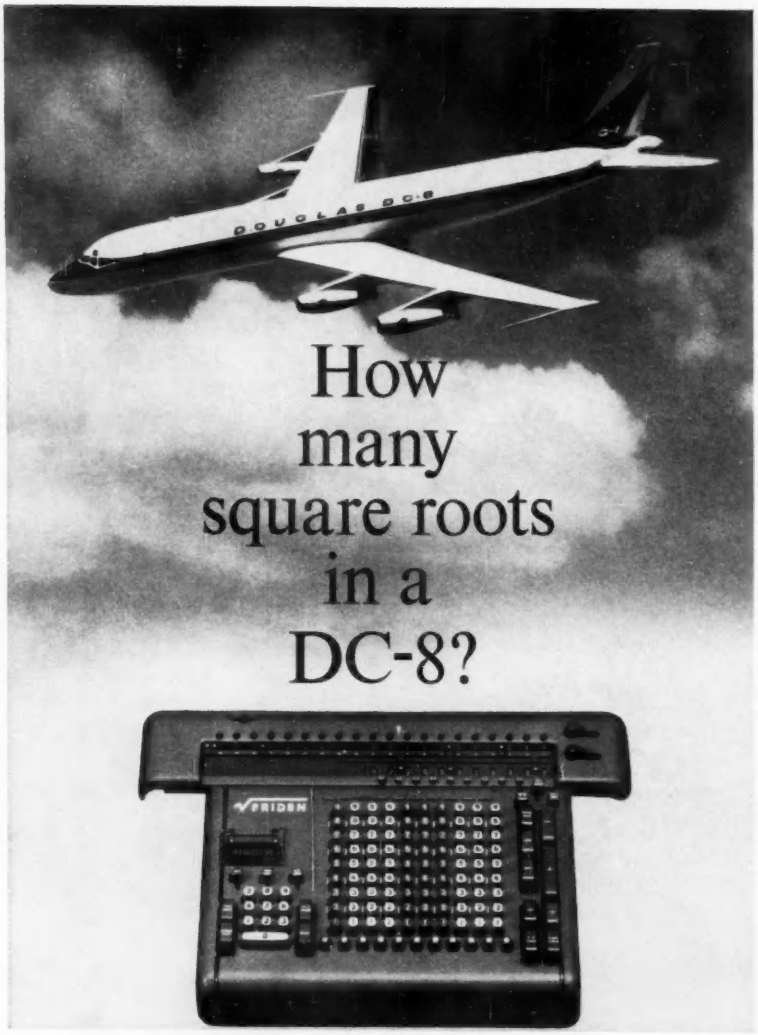
Republic Flow Meters Co. *(Subsidiary of Rockwell Manufacturing Company)*
2240 Diversey Parkway, Chicago 47, Illinois



Thousands? *Tens* of thousands would be more like it. The point is this: if Douglas had used conventional methods of extracting those square roots, the DC-8 would probably have been longer getting off the ground. Why? Because ordinary square root methods are a man-hour bottleneck and a troublesome source of errors.

How *does* Douglas get its square roots? With the Friden SRW... the only desk calculator in the world that automatically extracts square roots at the touch of a key. Douglas has 54 SRW's. And would hate to have to do without them.

You might not need 54 machines, but it's a rare engineering department that couldn't profit by the addition of at least *one* of these versatile engineering calculators. Ask your local Friden Man to show you what it can do. Or write: Friden, Inc., San Leandro, Calif.

THIS IS PRACTIMATION: automation so hand-in-hand with practicality there can be no other word for it.

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Sales, Service and Instruction Throughout the U.S. and World

Friden

WHAT'S NEW

(Continued from page 48)

power conversion and distribution, and drive systems engineering. The group will be based in Schenectady, N.Y., and will be headed by George W. Knapp, who was manager of equipment industries engineering for GE's Industrial Sales Operation.

The shift of management for process computers from the Computer Dept. in Phoenix, Ariz., to the Industry Control Dept. in Roanoke, Va., allows computer salesmen to specialize in data processing equipment and calls for industrial control specialists to sell computers for related applications. Named to head the industrial process control business was Raymond C. Berendsen; he had been manager of advance projects and marketing for GE's Ordnance Dept. Engineering and production for all computers will remain at Phoenix.

GD Consolidates S-C, Other Electronics

A new division of General Dynamics Corp., will consolidate the separable electronic activities of the corporation's several divisions with the former Stromberg-Carlson Div. Located in Rochester, N. Y., General Dynamics/Electronics will be headed by the president and general manager of S-C, James D. McLean.

First activity to be joined with S-C will be the instrument group at Convair-San Diego. This organization has sold a line of transducers for some time and has developed a high speed data acquisition system.

Japan Aims Instruments at U.S. Market

TOKYO—

A push toward expanded exporting is set to follow domestic growth in the Japanese instrument industry. Interviewed at the recent Osaka annual instrument show (CtE, Feb. '61, p. 41), instrument industry spokesmen pointed out that the Japanese market is too narrow to support its instrument business. Said Tetsuo Horiguchi, secretary of the Japan Electric Measurement Instruments Manufacturing Association, Japan must look abroad for instrument sales, as it does, as a trading nation, in other fields.

• **Aim to double sales**—Exports of Japanese instruments to a score of countries now account for about $2 million a year. The U.S. bought only $150,000 last year, but Japan

hopes to change that. Having conducted a market survey in the U.S. and a small equipment show in New York, the instruments association expects sales to double this year.

Much of the U.S. marketing plunge will revolve around very cheap products—some so cheap and inferior that their makers are not permitted membership in the association. For example, Horiguchi expects a big increase in the already hot U.S. market for very cheap Japanese voltmeters.

• **Quality, too**—Still the Japanese expect to make sales at the other end of the instrument spectrum: highly specialized laboratory instruments where the abundant supply of skilled cheap labor will be a big cost advantage. Horiguchi believes the Japanese basic instrument designs are comparable to the best U.S. and European techniques; but Japanese materials and production methods, he admits, are poor. The Japanese instrument men expect to be able to offer foreign buyers attractive delivery schedules—three to six months. A question to be resolved is how to handle after-the-sale service. The Japanese expect to answer this with an industry-wide service organization in the U.S.

News of Other Companies In the Control Field

New York Airbrake Co. has acquired Feedback Controls, Inc. as an autonomously operated subsidiary. Move is aimed at making the parent firm a single source for continuous process control systems.

Douglas Aircraft Co., Santa Monica, Calif., has begun negotiations with Midwestern Instruments, Inc. to work out an agreement that would give Douglas a substanial interest in the Tulsa, Okla., firm through acquisition of newly issued stock.

Electronic Specialty Co. and **American Electronics, Inc.** have called off their merger discussions. Main reason for the change in plans involved the firms' inability to reach a basis for exchange of stock. However, the merger of D. S. Kennedy & Co. into ESC has taken place as planned, subject to stockholder approval.

Infrared Industries, Inc., Waltham, Mass., and **Cramer Controls Corp.**, Centerbrook, Conn., have agreed to terminate their merger talks, giving as a reason their failure to find sufficient areas of mutual benefit.

Hoffman Electronics Corp., Los Angeles, has formed an Instruments

INERTIAL QUALITY

SINGLE AND 2 AXIS ACCELEROMETERS

Highly precise and accurate, Kearfott's accelerometers are pendulous devices which sense airframe acceleration forces acting on them.

A pendulum utilizing a unique Hooke's joint suspension displaces as a function of acceleration. An AC pickoff signal is rectified and applied to voice coils restoring the pendulum to null. The DC required for restoration is proportional to acceleration. Typical characteristics for these units include range of ±25 g's, scale factor of 5.0 ma/g, linearity of ±0.005% and threshold of 2 x 10^{-7} g's.

CHARACTERISTICS:

TYPE NO.	SINGLE AXIS F2401	SINGLE AXIS 429037	TWO AXIS 326778-1
Range of Measurement	±20g	±25g	See above
Scale Factor (output)	5.0000 ma/g	5.0000 ma/g	
Operating Temperature	155°F ±5°F*	50°F and +160°F	
Threshold	5 x 10^{-7}g	Less than 2 x 10^{-7}g	
Zero Stability	±0.05 milliradian	±.00005g day to day	
Vibration	Up to ±10g peak from 20 to 2000 cps	Up to ±5g peak from 20 to 2000 cps	
Storage Temp.	−65°F to +200°F	−60°F to +170°F	
Scale Factor Variation	±.01% randomness	±0.01% randomness	
Excitation	6 volts, 3860 cps**	6 volts, 4000 cps**	3.4 volts, 4000 cps***
Natural Freq.	180 cps	210 cps	160 cps
Freq. Resp.	Flat to 250 cps	Flat to 160 cps	Flat to 100 cps
Shock	60 g's	30 g's	30 g's
Weight	4 oz.	7 oz.	2 lbs.

*Available for 180°F.
**Carrier frequency to 100 Kc may be used.
***When tested with Kearfott A3501-01 amplifier.

Write for complete data

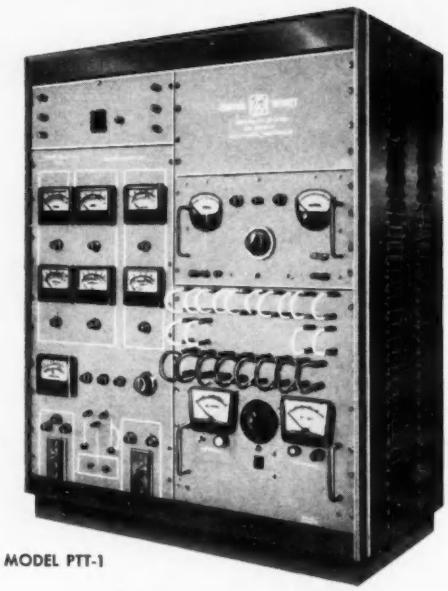
KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

CIRCLE 203 ON READER SERVICE CARD

Power Transistor Test System

FLEXIBLE, ACCURATE COMPLETE LAB SYSTEM



MODEL PTT-1

APPLICATIONS ENGINEERING
QUALITY CONTROL
RECEIVING INSPECTION

For the first time, a complete power transistor test system is available in one "package." It provides complete DC characterization of transistors with output ranges up to 20 amperes and input current ranges from 10 micro-amperes to 2 amperes. The patch panel arrangement is such that any meter or power supply can be connected to the test transistor. Readout of breakdown voltage, emitter floating potential, saturation voltage, leakage current, input voltage and current plus output voltage and current are possible with this system. Individually designed systems for special requirements are also available.

WRITE FOR INFORMATION ON COMPLETE SOLID STATE RELAY LINE

SOLID STATE RELAYS—for microsecond switching application extremely resistant to high shock and vibration environments.

See Curtiss-Wright at IRE — Booth 1521-23

INTER MOUNTAIN INSTRUMENTS BRANCH • ELECTRONICS DIVISION

CURTISS WRIGHT

CORPORATION • P. O. BOX 8324, ALBUQUERQUE, N. M.

SOLID STATE RELAYS • TRANSISTOR TEST INSTRUMENTS AND SYSTEMS • DIGITAL DATA ACQUISITION AND PROCESSING SYSTEMS

204 CIRCLE 204 ON READER SERVICE CARD

WHAT'S NEW

Div. to make precision electromechanical equipment for industry and the military. New products will be developed to supplement aircraft instruments, computers, and gyros currently being produced.

The Dow Chemical Co. has set up an Instrument Systems Research Laboratory at its plant in Midland, Mich. Purpose of the lab will be to assist Dow engineers and production men with instrument problems, with major emphasis to be placed on stream analyzers, computers, and specially designed equipment.

General Railway Signal Co. has acquired a controlling interest in Cardion Electronics, Inc., Westbury, N.Y. Cardion's capabilities in electronic control and communication equipment are expected to broaden GRS's scope in electronic railway, highway, and air traffic control systems.

Laboratory for Electronics, Inc. of Boston has reached an agreement with Eastern Industries, Inc., Hamden, Conn., in which Eastern would be merged into LFE. Stockholders still have to vote on the plan.

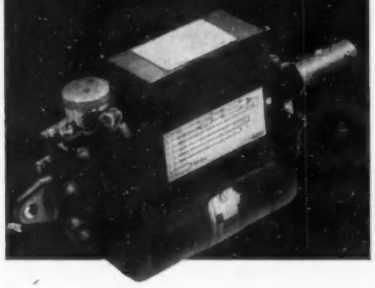
The Siegler Corp. has received stockholder approval for the merger of Jack & Heintz, Inc. into the Los Angeles company. J & H shareholders also approved the plan.

International Resistance Co. has entered the semiconductor field through its recent acquisition of North American Electronics, Inc. of Lynn, Mass. The Philadelphia company will operate NAE, maker of 600 types of silicon rectifiers and zener diodes and silicon controlled rectifiers, as an independent concern.

Space Technology Laboratories, Inc. has formed a new division, STL Products, to sell on the commercial market scientific and technical devices developed from STL research in missile and space programs. First products include what is called the world's fastest electronic camera and a portable atomic frequency standard.

Daystrom, Inc. now has a formal agreement with Nationwide Leasing Co. of Chicago through which Nationwide will buy Daystrom Industrial Products Group equipment—even entire process control systems—for lease to a customer.

COMPACT AiResearch 60 cycle Actuators *for ground use . . .*



Inexpensive, lightweight 60 cycle motor driven actuators with integral magnetic brakes* are now being manufactured by AiResearch for ground radar, ground support and shipboard use.

Unequalled in 60 cycle performance, these extremely compact, lightweight actuators range from fractional hp motor size up to any desired hp in single phase, two phase and three phase design for a wide variety of applications.

The above-pictured actuator is used in a ground radar system. It is driven by a single phase 60 cycle ac fractional hp electric motor and can be furnished with a feedback potentiometer for use in servo applications. The entire unit weighs only 2½ lb. and is rated at 200 lb. operating load.

OTHER ELECTROMECHANICAL COMPONENTS AND SYSTEMS

A C and D C Motors, Generators and Controls • Static Inverters and Converters • Linear and Rotary Actuators • Power Servos • Hoists • Temperature and Positioning Controls • Sensors • Programmers • Missile Launchers • Radar Positioners • Power Supplies • Williamsgrip Connectors

Your inquiries are invited.

* *patented 60 cycle operated magnetic brake*

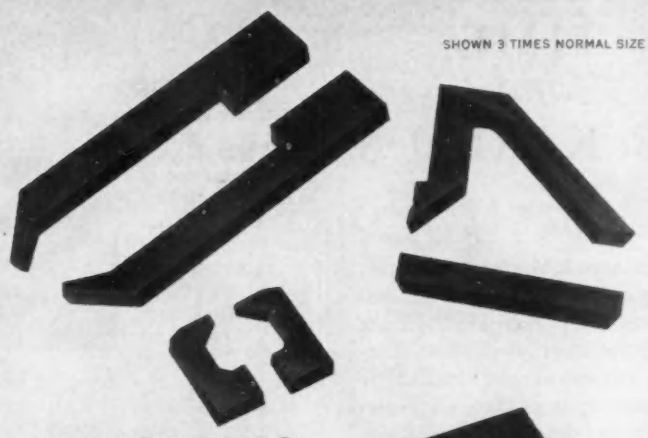
THE GARRETT CORPORATION

AiResearch Manufacturing Division

Los Angeles 45, California

CIRCLE 239 ON READER SERVICE CARD

SHOWN 3 TIMES NORMAL SIZE



RECORDING HEAD FERRITE

Kearfott's new CN-20 nickel-ferrite, specifically developed for recording head applications, is a sintered material which operates most efficiently in the 10 kc to 750 kc frequency range. CN-20 imparts superior magnetic and mechanical properties, is insensitive to mechanical stresses of potting compound during curing, is magnetically stable under temperature variation and has uniform magnetic properties. CN-20 heads have negligible deviations in inductance to temperatures as high as 160°F, using gaps of .0010 or .0015 inches.

Production quantities of complex shapes are immediately available. Dimensional tolerances of 0.0001 inch and finishes of 16 to 32 micro-inches are standard . . . electroplated surfaces for unusual wear resistance also available.

TYPICAL CHARACTERISTICS

Initial Permeability at 100 kc	800
Saturation Magnetization (DC) at 16 oersteds	3680 gauss
Residual Magnetization	2565 gauss
Coercive Force	0.19 oersteds
Temperature Coefficient of Initial Permeability (−20°C to +100°C)	1.0% °C
Curie Temperature	150°C
Resistivity	10^4 ohm-cm

All magnetic properties are held within a tolerance of ±15%

Write for complete data

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

CIRCLE 205 ON READER SERVICE CARD

SPACE, TIME *and* DR. KARPLUS

$$\frac{\partial}{\partial t} \rightarrow \Delta$$

Enthusiasm & Equipment for analog computing and model building have been purveyed by Philbrick Researches since 1946. The processes synthesized and studied by such techniques as these are generally the sort described by *total differential equations.*

When Field Problems place *partial differential equations* on the stage, the analog impresario recasts them as the former kind by lumping in space. As to time, though he may scale it, he is loath to lump it. Transient fields are transformed by him into models which are Discrete in Space, but Continuous in Time.

Numerical solution of field problems, whether carried out by a Giant Digital Brain or by a tiny human one, proceeds by transforming to *difference equations.* Everything is made discrete: even the dependent variables of the field.

An intermediate technique is recommended by Dr. Walter J. Karplus*, which is called DSDT: for Discrete Space and Discrete Time. He retains the continuity and convenience of analog voltage for field variables, but formulates the solution in a novel manner with difference equations. The Karplus method† is compatible with analog equipment of the kind we make and sell, and we should naturally be happy to send data on the subject to responsible enquirers.

*Associate Professor, University of California, Los Angeles
†Philbrick Researches is licensed exclusively by Dr. Karplus to apply his DSDT invention.

GEORGE A.
PHILBRICK
RESEARCHES, INC.
127 Clarendon Street, Boston 16, Mass.

IMPORTANT MOVES BY KEY PEOPLE

Calvert Manages Lear Division

A recent addition to the staff of Lear, Inc., Robert D. Calvert, has become general manager of the company's Electro - Mechanical Div. in Grand Rapids, Mich. Calvert joined the firm early last year following five years with GE and nine years with Hughes Aircraft Corp.

The new Lear general manager was a marketing product manager for the Semiconductor Div. of Hughes at the time he left that company. Calvert started at Lear as assistant general manager under former vice-president and general manager, T. K. Greelee.

Aker New Engineering V-P at ITT Industrial Div.

New vice-president - engineering of International Telephone and Telegraph Corp.'s Industrial Products Div., based in San Fernando, Calif., is C. M. Aker. The new appointee joined the division in 1957, becoming director of engineering about a year later.

Aker's diversified background includes four years at Lockheed Aircraft Corp. as a senior research engineer, a post he held just previous to joining ITT. Prior to his association with Lockheed he was an electronics engineer at the Raytheon Co., working in the development of radar equipment. He began his engineering work in 1943 at the Underwater Sound Development Laboratories at Harvard.

Boyle, Green in New Posts at Collins Radio

John H. Boyle has become general manager of Collins Radio Co.'s new Communications and Data Processing Div. The division was formed last year (CtE, Jan. '61, p. 155) to integrate advanced communications, switching, and data transmission developed by Collins. Also at Collins, James H. Green, Jr., has been appointed director of the Space Communications Div. of the Alpha Corp., the systems management subsidiary of the company.

Liccardi New Electro-Mech Chief Engineer

Anthony J. Liccardi has taken over the post of chief engineer at Electro - Mech Corp. of Norwood, N. J. In this capacity he will direct all engineering personnel involved in the design of the firm's control systems as well as the engineering group at the Reliance Instrument Div., which manufacture electronic combustion controls.

Prior to joining Electro-Mech, Liccardi was at the Loewy Hydropress Div. of Baldwin-Lima-Hamilton Corp.

Other Important Moves

T. E. Velfort, Jr., has been named chief electronics engineer for the Shockley Transistor unit of Clevite Corp. He was until recently with Moore Associates and Lynch Communications Systems, Inc.

John N. Daniel is the division manager of Square D Co.'s newly formed commercial control division in Asheville, N. C. Daniel has been with Square D since 1947.

Max Lehrer has taken the newly created position of director of defense business development for RCA's Defense Electronic Products group. For the past two years he has been assistant staff director of the U. S. Senate Space Committee.

Harold N. Morris has become engineering manager for the new RCA computer systems plant at Palm Beach Gardens, Fla. With the company since 1954, Morris has served on the RCA Missile Test Project.

James E. Gambrill has been named general sales manager of Moore Products Co. of Philadelphia.

Obituary

Anton W. Schmitz, 55; manager of equipment engineering, General Electric Co. Industry Control Dept.; in Roanoke, Va., December 2.

KEARFOTT SIZE 5 COMPONENTS

FOR SERVO SYSTEM MINIATURIZATION

SHOWN ACTUAL SIZE

A complete family of Size 5 components for every servo system function is now available from Kearfott. This series offers the system designer complete latitude in miniaturization of his second-generation systems, with the performance and reliability heretofore found only in much larger units.

Stainless steel housings, shafts and bearings protect the units against environmental extremes and contribute to stability under shock, vibration, and temperature fluctuations. • Standard 26-v, 400 cps excitation. • Synchro and resolver accuracy ±10 min. • Operating temperature range −55° to +125°C. Computer-designed for optimum performance.

CHARACTERISTICS

SYNCHROS

	VOLTAGE (400 cps)	CURRENT (amps)	IMPEDANCE INPUT	IMPEDANCE OUTPUT	T.R.	NULL (mv)	ERROR (min)
Transmitter							
CJO 0565 100	26	.045	576/74.7	94.2/71.4	.454	34	10
Control Transformer							
Low Z-CJO 0555 100	11.8	.0408	250/73	1085/72	1.765	34	10
High Z-CJO 055 900	11.8	.0202	550/74	2390/73	1.765	34	10
Differential							
CJO 0595 100	11.8	.0408	250/72	313/69.8	1.154	34	10
Resolver							
Low Z-CJO 0585 100	26	.0485	537/64.7	677/74	1.0	34	10
High Z-CJO 0589 100	26	.0145	1795/68.1	2210/76	1.0	34	10

Weight: 0.90 oz; Length: 1.250 in.

SERVO MOTORS

	J126-06	J126-02
No-Load Speed	9800 rpm	9800 rpm
Stall Torque	0.10 in. oz	0.10 in. oz
Rotor Moment of Inertia	0.175 gm cm²	0.175 gm cm²
Voltage φ1/φ2 (400 cps)	26/36-CT	26/26
Power Input/Phase	1.7 w	1.7 w
Duty	continuous at stall	

SYNCHRONOUS MOTOR

	CJO 0172 200
Pull-In Torque	0.06 in. oz
Pull-Out Torque	0.10 in. oz
Pull-Out Power	4 w
Length	1.24 in.

MOTOR GENERATORS

MOTOR	CJ4 0812 001	CJ0 0812 650	CJ0 0813 200
Voltage φ1/φ2 (400 cps)	26/36-CT	26/36-CT	26/26
Power/φ	1.5 w	1.5 w	1.5 w
No-Load Speed	8000 rpm	8000 rpm	8000 rpm
Stall Torque	0.10 in. oz	0.10 in. oz	0.10 in. oz
GENERATOR			
Voltage (400 cps)	26 v	26 v	26 v
Power	1.5 w	1.5 w	2.0 w
Volts/1000 RPM	0.1 v	0.1 v	0.5 v
Null	1.3 mv	10 mv	6.7 mv

Weight: 1.05 oz; Length: 1.507 in.

GEARHEADS, BRAKES, CLUTCHES

Size 5 gearheads range in reduction ratios from 20:1 to 1019:1 for servomotors and motor tachometers above. In addition, Size 6 clutches, brakes, and brake-clutches are available.

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Little Falls, New Jersey

GENERAL PRECISION, INC.
Other Divisions: GPL, Librascope, Link

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The Industry's Widest Variety

When weight and space are critical and it becomes essential to use the smallest and lightest production servos available, Sperry Rand's Wright Division offers you the industry's widest variety of advance components.

Typical of this variety are Wright Size 8 Servos, a few of which are shown above. Normal Torque or High Torque. High Acceleration or Exceptional Acceleration. Normal Torque to Power or High Torque to Power. You name it, Wright has it. And 200°C operation is standard!

Telephone Durham (919) 682-8161 or write for get-acquainted literature and name of our nearest representative.

Servo Motors, Motor Tachometers, Geared Servos, Synchros, Servo Packages, and Spin Motors in frame sizes from Size 8 through 30.

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Durham, North Carolina

ABSTRACTS

Automatic warehousing payout

From "Mechanized Warehousing of Case Goods", by A. Spinanger, Procter & Gamble Co. Paper No. 60-WA-95 presented at the Winter Annual Meeting of the American Society of Mechanical Engineers, New York, Nov. 27-Dec. 2, 1960.

Whether or not automatic warehousing equipment and controls will be installed is, like most other major control jobs, a matter of prior economic justification. A thorough economic review involves the study of all realistic alternatives to determine how much of the over-all objectives, including long-range and short-range needs, can be obtained by minimum prudent investment and optimum equipment and manpower usage. With such aims in mind, Spinanger discusses an actual study in which are included the many economic and technical factors involved in determining how to mechanize warehousing operations to handle case goods. He considers four different levels (manual, semiautomatic, automatic for one brand size, and automatic for three brand sizes) and charts payout alternatives for them in terms of cases per day handled and the number of brand sizes. Spinanger found that high equipment costs can lead to payouts of four to eight years.

Each possible improvement, regardless of technical complexity, or overall functional impact, must be viewed in the light of its own economics. Spinanger gives two diverse cases:

1) "Two-way radios were installed in a warehouse . . . to improve the coordination of clamp truck and train case-handling operations. The initial justification estimated $20,000 gross saving on a $10,000 investment in radios. After six months' experience with the radio-directed operation, gross savings on the order of $100,000 appeared more reasonable. A significant part of this saving was due to capacity increase. Several improvements in handling techniques, coordinated by the two-way radio, had resulted in a lower-cost warehousing system."

2) "In a recent justification study, it was found that if an automatic unit-load former could have been purchased for $1 [**estimated actual cost is about $30,000—Ed.**] and installed with a three-product accumulation

system, the installation would still have taken four years to pay out. Costs for 'accessories' alone (case detecting and diverting equipment, flow racks, powered conveyor sections, rack discharging mechanisms, control wiring, etc.) led to such a payout. This justification is not unrepresentative; it was calculated for what seemed to be a good potential unit-load-former application."

Talking to a computer

From "A Method of Voice Communication with a Digital Computer", by S. R. Patrick and H. M. Willett, Air Force Cambridge Research Labs. Paper presented at the Eastern Joint Computer Conference, New York, Dec. 13-15, 1960.

At Cambridge, a speaker utters a word into a microphone, the microphone feeds a vocoder (a device that converts spoken sounds to time-frequency patterns of spectral energy), then the analog spectral pattern is converted to equivalent digital representation, the digits enter a computer, the computer searches its pre-stored set of word-masks, and finally a typewriter prints out the spoken word. Elapsed time: 1½ sec per word.

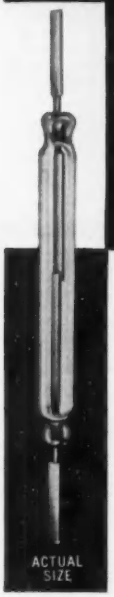
"To develop a set of masks (giving the computer a particular vocabulary) the speaker repeats a word several times. A mask is then computed which optimizes a certain recognition parameter. The speaker then must type into the computer the printed word he wishes associated with his spoken word . . . If the speaker's own voice is used to prepare masks of the words he wishes to be recognized, correct identifications are made with almost 100 percent accuracy. In other cases the degree of success is highly dependent upon the particular individuals involved."

Besides the basic English-speech/English-print relationship, other programs tested include:

- ▶ The voicing of a word in one language followed by its typewriter association in a second language, resulting in a crude translator.
- ▶ A computer routine enabling a speaker to say a sequence of words related to solving an arithmetic expression, from 0 to 9 and operations like *add*, *multiply*, and *equals*, and causing a typewriter to print out the answer to the arithmetic expression.
- ▶ A speaker recognition pattern identifying the talker and the spoken word with appropriate comments.
- ▶ An adaptive program enabling the computer to automatically reorient itself to a new speaker's voice.

CLAREED®

Sealed Contact Relays...
for contamination-free operation...positive on-off switching



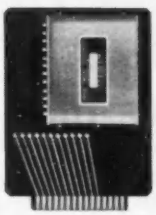
CLAREED solves the vexing problem of contact contamination. Its sealed, gold-plated contacts operate indefinitely in an in-built ideal environment, give positive on-off switching for up to millions of cycles. It is a relay you can install and forget.

This maintenance-free operation makes CLAREED sealed contact relays ideal components for such critical applications as transistor drives, computers, data processing equipment and many other high-speed devices.

CLAREED design is simplicity itself—a pair of magnetically operated contacts, hermetically sealed in an atmosphere of inert gas within a glass capsule. Compact size permits almost unheard-of flexibility of assembly and application.

Typical space-saving Clareed Relay Assemblies

Cylindrical can, containing CLAREED switch capsules which form core of common coil. Numerous variations to meet design needs.



CLAREED relay consists of 12 switch capsules enclosed in a rectangular container and mounted on printed circuit board.

CLAREED relay module for printed circuits. Quick mounting. High component density. Sturdy steel case provides magnetic shield.

If you use relays, it will pay you to know all about CLAREED relays...a new concept in relay design. To obtain Bulletin CPC-10, address: C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Limited, 840 Caledonia Road, Toronto 19, Ontario. Cable Address: CLARELAY.

See Clareed Relays in working logic modules... No tubes, no transistors.
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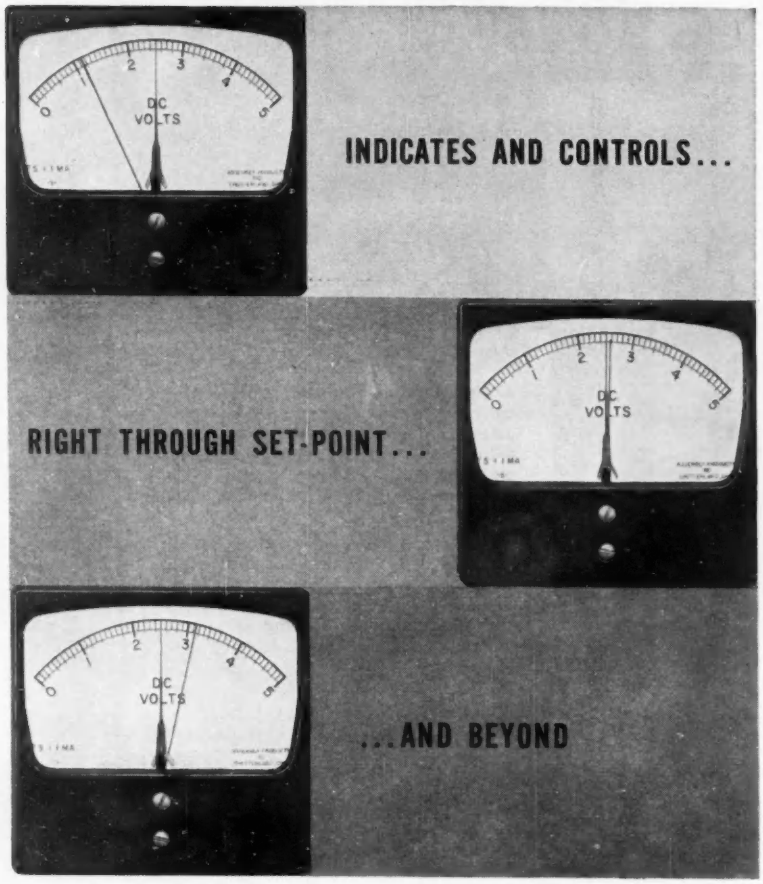
C. P. CLARE & CO.
Relays and Related Control Components

CIRCLE 209 ON READER SERVICE CARD

NEW—CONTINUOUS READING METER-RELAY



GIVES CONSTANT CONTROL

UPSCALE OR DOWN

API's new Continuous Reading Meter-Relay (CRMR) can do a diversity of control jobs for you. It will monitor and control just about any variable that can be translated to electrical values. It will handle low-level microamp or millivolt signals without amplification. In many applications, the CRMR's high sensitivity will permit simplification of control circuitry. In any application, it will give accurate (±2% or better), non-cyclic control.

The CRMR is simple. It consists of a D'Arsonval meter with toggle-mounted contacts; a load relay does the control switching. No signal-sampling interrupters are required. Reset is automatic and instantaneous.

Reliability? The CRMR is right now in service on such critical applications as monitoring radiation level.

Our Bulletin S-2-1 shows how the CRMR works, and gives full details on available ranges and prices. The latter, not incidentally, are a lot less than you might expect for so versatile an indicating control.

ASSEMBLY PRODUCTS, INC.

Chesterland 77, Ohio

S.A. 2203

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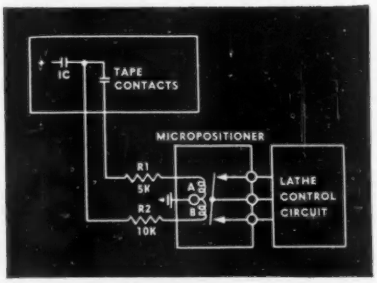
BARBER COLMAN

Ultra-sensitive relays

HELPFUL DATA FOR YOUR CIRCUITRY IDEA FILE

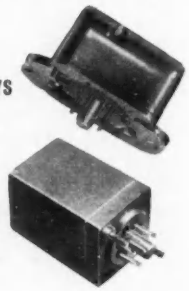
The circuit drawing below indicates just one of the hundreds of ways many manufacturers utilize Micropositioner® polarized relays to solve complex control problems.



MICROPOSITIONERS® IN BARBER-COLMAN TAPE-R-GUIDE LATHE CONTROL CIRCUIT

Lathe operating data is fed in on punched tape. Micropositioner ultra-sensitive magnetic latching relays detect the tape signals, which are too small for conventional relays. Coil B is energized whenever the interrogating contacts (IC) close. Each time a hole in the tape occurs coil A becomes energized, and because R1 is less than R2, the relay changes over and a signal is passed to the control circuit. The relay remains in the last position until the next hole is reached, when it again changes over.

If your projects involve similar types of control, why not test the Micropositioner in your circuits? Write for technical bulletins.



BARBER-COLMAN MICROPOSITIONER® POLARIZED D-C RELAYS

Operate on input power as low as 40 microwatts. Available in three types of adjustment: null seeking . . . magnetic latching "memory" . . . and form C break-make transfer. Also transistorized types with built-in preamplifier. Write for new quick reference file.

BARBER-COLMAN COMPANY

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CIRCLE 240 ON READER SERVICE CARD

NEW BOOKS

Machine Translation Report

LINGUISTIC AND ENGINEERING STUDIES IN AUTOMATIC LANGUAGE TRANSLATION OF SCIENTIFIC RUSSIAN INTO ENGLISH, PHASE II. *Erwin Reifler et al.* 504 *pp. Published by the University of Washington Press, Seattle.* $10.

Papers by seven members of an Air Force-sponsored project charged with preparing a MT-operational Russian-English lexicon. The free-form approach is used, i.e., the lexicon includes not only customary forms such as the present infinitive of verbs but all relevant forms. The linguistic section contains a history of machine translation (with 19-page bibliography), a solution to the idiom problem, word counts on a 31,043-word corpus, and simulated MT's of 111 Russian scientific texts. The engineering part covers the role of the digital computer in Russian-English MT and the block analysis of Greek sentences (which share certain problems with the Russian), and presents design specifications for a suitable computer. MPS.

New in series

PRINCIPLES OF CONTROL SYSTEMS ENGINEERING. *Vincent Del Toro and Sydney R. Parker, The City College of New York.* 686 *pp. Published by McGraw-Hill Book Co., Inc., New York.* $14.50.

Intended as a text for a senior or graduate level course in feedback controls, this book (the latest in McGraw-Hill's series in Control Systems Engineering) uses the standard sequence for presenting the basic subject material and does an excellent job of covering the details. The first four (of five) parts comprise the basic text. They consist of an introduction and mathematical background, the time domain, frequency domain, and root locus approaches. Each part is well planned and clearly presented, coverage is reasonably complete, and a few worthwhile original ideas are included.

Part V, Computer Approach, includes brief chapters on analog and digital computers and one on self-adaptive control systems. These are interesting reading but serve only as an introduction to the topics considered.

The strong points of the text are clarity in presentation, inclusion of

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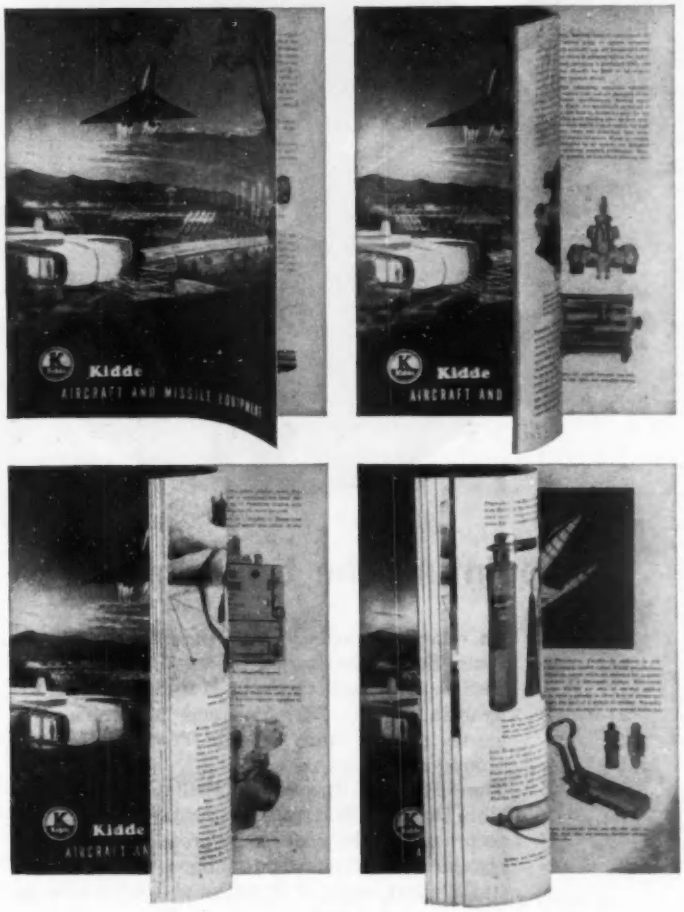

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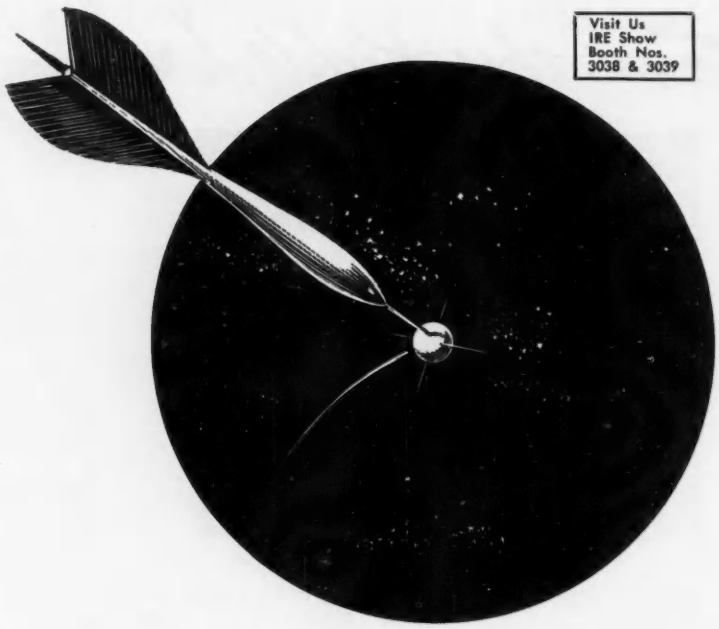
CIRCLE 211 ON READER SERVICE CARD 211



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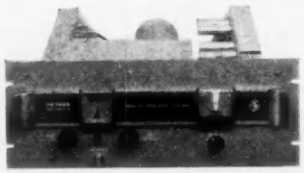
Pin-pointing the time dimension

To establish precise orbital parameters, Hermes Ultra Stable Oscillators, Model 101C, are being used as frequency standards in timing systems for Transit, Project Mercury, and Minitrack programs, and by many Missile Tracking Stations around the world.

These Hermes Ultra Stable Oscillators are of such high stability that global time synchronization accuracies in the *order of microseconds* are now possible. Numerous reports have been received stating that many of these units exhibit average drift rates of 1 part in 10^{10} per day . . . in some instances, less than 1 part in 10^{10} per week!

The Hermes Ultra Stable Oscillator, Model 101C, is now in its fifth year of production. Every unit is pre-aged at the factory until it exhibits a frequency stability of better than its guaranteed stability of 5 parts in 10^{10} per day. Hermes Ultra Stable Oscillators are *available from stock.*

Write for Technical Bulletin USO



Hermes USO, Model 101C. Also available . . . Regenerative Frequency Dividers providing outputs at 100kc, 10kc, and 1kc, and Frequency Multipliers providing phase stable outputs of 10Mc and 100Mc.

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NEW BOOKS

physical as well as mathematical interpretations wherever possible, presentation of a wide variety of systems and components from many fields of engineering, an adequate number of illustrative examples, and a good selection of problems at the ends of the chapters. These features make the book a good classroom text and also should make it valuable to the engineer interested in home study. The only apparent weaknesses are due to omissions: the Nichols chart is barely mentioned, the *M-N* contour chart does not appear, multiple loop systems are mentioned only in the section on block diagram manipulation, and compensation is treated solely as a cascade filter problem except for brief treatment of tachometer feedback.

George J. Thaler
U. S. Naval Postgraduate School

ICIP Papers Published

INFORMATION PROCESSING. *Proceedings of the International Conference on Information Processing, Unesco, Paris, June 15-20, 1959. 520 pp. Published jointly by Unesco, Paris, R. Oldenbourg Verlag, Munich, and Butterworths Scientific Publications, London, 1960. $25 from the Columbia University Press, 2960 Broadway, New York 27, N. Y.*

This is the full text in English or French (about 90 percent English) of all 61 papers selected for the plenary sessions of the above conference. There are abstracts in English, French, German, Russian, and Spanish; and summaries in English or French of the 65 lectures give at specialized meetings.

The presentations have been organized by subject matter into seven chapters. Methods of Digital Computing covers such things as the solution of partial differential equations, the effect of rounding errors, and logarithmic and linear programming. Papers in chapter 2 are devoted to finding a universal, problem-oriented language for use with computer. Chapter 3, dealing with machine translation, discusses problems of syntax and setting up an automatic dictionary, and includes examples of Russian-English and English-Russian MT.

Chapter 4 has papers on character and speech recognition and machine learning — general problem-solving techniques, proving logical and geometric theorems, and elements whose performance changes with experience.

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CONVAIR/POMONA is the developer of RED-EYE, a one-man, shoulder-launched guided missile ... a new lightweight weapon that will strike swiftly with pin-point accuracy ... a weapon that will ensure our ground forces of the Army and Marine Corps an effective means of combatting low-flying enemy aircraft.

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EDUCATION	BS	MS	PhD	DATE(s):		BS	MS	PhD	DATE(s):
EE	☐	☐	☐	_____	Physics	☐	☐	☐	_____
ME	☐	☐	☐	_____	Other:_____	☐	☐	☐	_____
Mathematics	☐	☐	☐	_____	_____	☐	☐	☐	_____

School (Highest Degree)_____

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Please indicate your fields of experience below.

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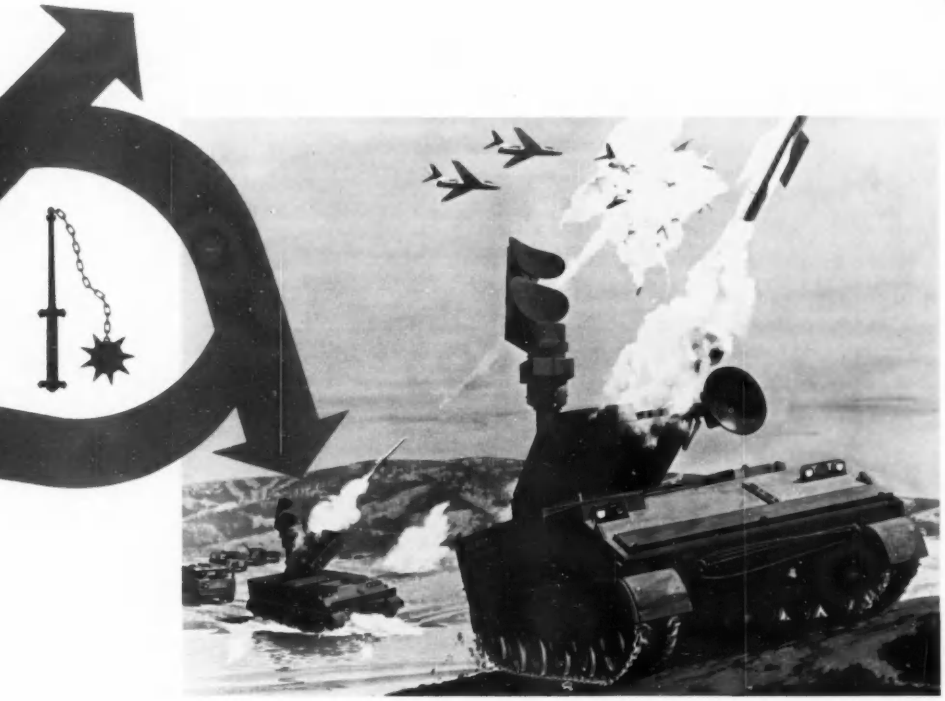

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NEW BOOKS

Logical design of computers, ways of speeding up their programming and operation, such as time sharing, are discussed in Chapter 5. Promising developments such as thin magnetic film, cryogenic components, and microwave solid state devices are reported on in chapter 6, and the final chapter is a miscellaneous one.

As Prof. Howard H. Aiken, president of the conference, pointed out in his closing speech, papers on the use of computer-type devices for automatic control of machine tools and plant facilities are conspicuous by their total absence. MPS.

Analog Computer Primer

BASICS OF ANALOG COMPUTERS. *Thos. D. Truitt and A. E. Rogers. 400 pp. Published by John D. Rider Publisher, Inc., New York, 1960. $12.50.*

Like its "pictured text" predecessor on digital computers, this book assumes little previous knowledge on the part of the reader. The first section manages to explain such things as basic mechanics and calculus while drilling home what an analog is, how analog devices function, and why certain problems can be solved better on an analog computer than a digital one. After brief looks at passive element computers, mechanical and electromechanical analog computers, the ac analog computer, and the digital differential analyzer part two settles down to study the building blocks of the general purpose dc analog computer. Part three covers programming and applications of the same machine, and ends with a glossary of terms. MPS.

Idea Source

PRACTICAL ROBOT CIRCUITS. *A. H. Bruinsma. 125 pp. Published by the Macmillan Co., New York. $3.95.*

Two demonstration-model robot systems are described here. One resembles a dog, can "see" and "hear" in stereo with photoelectric cells and microphones, "feel" objects and temperatures with microswitches and negative temperature coefficient resistors, move about, and is equipped with acoustic radar. The other is stationary, and is designed to play tic tac toe. Besides making interesting reading, this book is a source of ideas for solving the more ordinary problems of robot circuitry.

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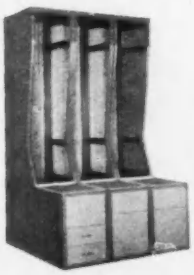

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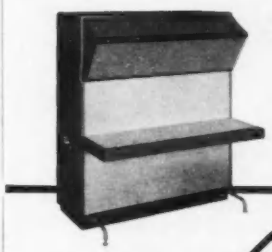

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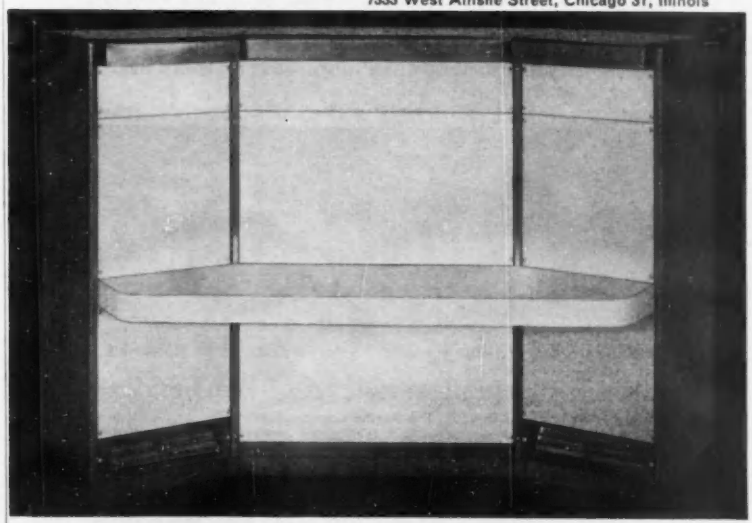

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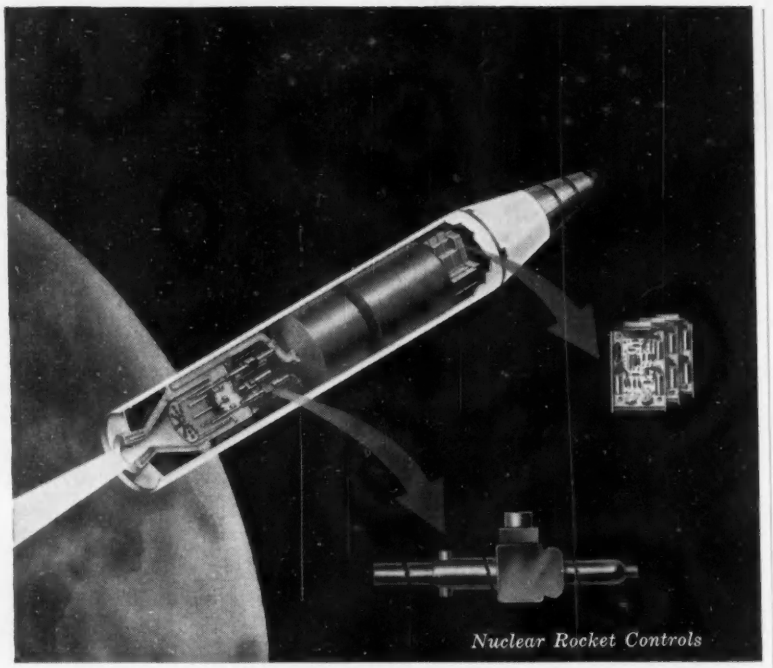

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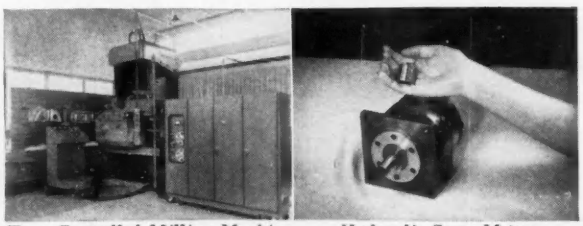

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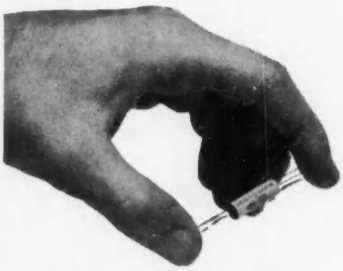

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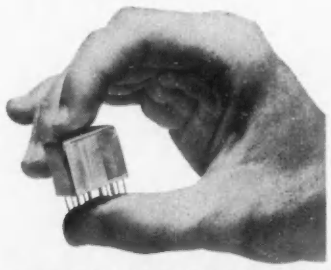

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MEETINGS

MARCH

Instrument Society of America, 11th Annual Spring Conference on Instrumentation for the Iron and Steel Industry, Roosevelt Hotel, Pittsburgh, Pa. March 8-9

Institute of Radio Engineers, International Convention, Coliseum and Waldorf Astoria Hotel, New York, N. Y. March 20-23

American Society for Metals, 13th Western Metal Exposition and Congress, Pan Pacific Auditorium, Los Angeles, Calif. March 20-24

Temperature—Its Measurement and Control in Science and Industry (Fourth National Symposium), sponsored by National Institute of Physics, ISA, National Bureau of Standards, Veterans Memorial Hall, Columbus, Ohio March 27-31

APRIL

Instrument Society of America, 13th Annual Symposium — Electronic Process Instrumentation, sponsored by N. J. Section, Hotel Essex House, Newark, N. J. April 4

Third Symposium on Information and Decision Processing, sponsored by IRE and Purdue University, Purdue University, Lafayette, Ind. April 12-13

Instrument Society of America, Seventh National Symposium on Instrumental Methods of Analysis, Shamrock-Hilton Hotel, Houston, Tex. April 17-19

Institute of Radio Engineers, 13th Annual Southwest IRE Conference and Electronic Show (SWIRECO), Dallas Memorial Coliseum, Dallas, Tex. April 19-21

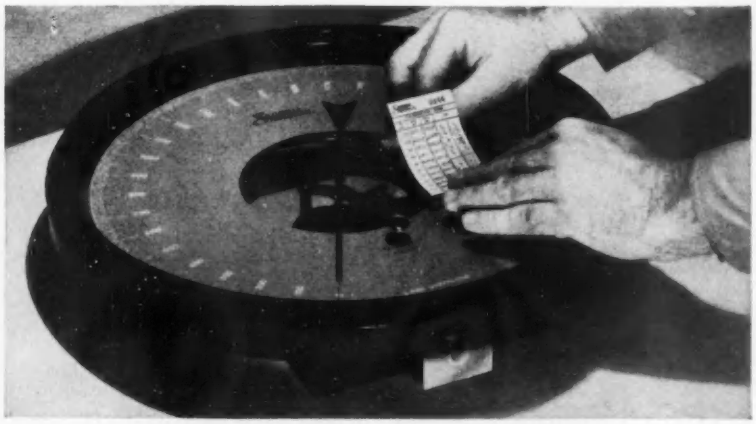
Institute of Radio Engineers, Seventh Region Technical Conference and Trade Show, Westward Ho Hotel, Phoenix, Ariz. April 26-28

Instrument Society of America, Seventh National Aero-Space Instrumentation Symposium, Adolphus Hotel, Dallas, Tex. April 30-May 4

MAY

Institute of Radio Engineers, 13th Annual National Aerospace Electronics Conference (NAECON), Miami and Biltmore Hotels, Dayton, Ohio May 8-10

Western Joint Computer Conference, sponsored by IRE, ACM, AIEE, Ambassador Hotel, Los Angeles, Calif. May 9-11



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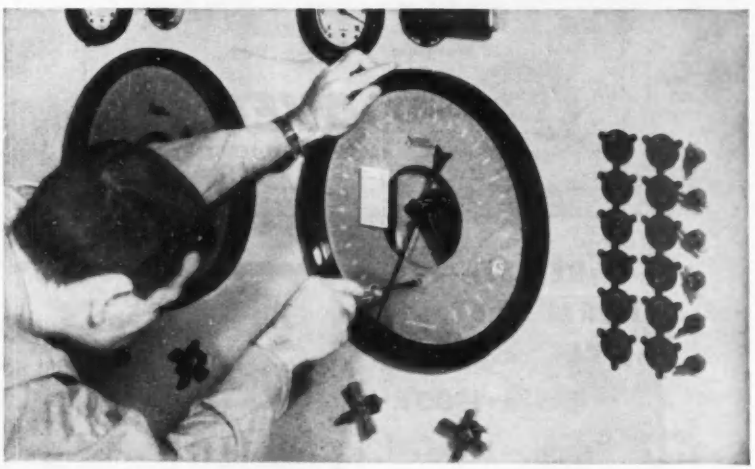

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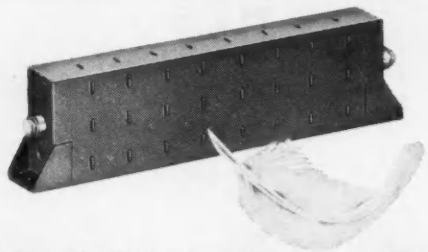

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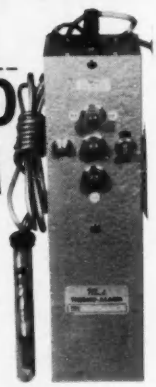

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508—Transistor Switches for Industrial Service, March 1961, 24 pp. Industry requires reliable, inexpensive, and fast switching devices. This special report thoroughly covers one possible solution to this requirement—transistor logic modules packaged for industrial use. Topics include: how transistors perform logic functions, available systems and components, tips on selection and use, and case studies of industrial applications. 65 cents.

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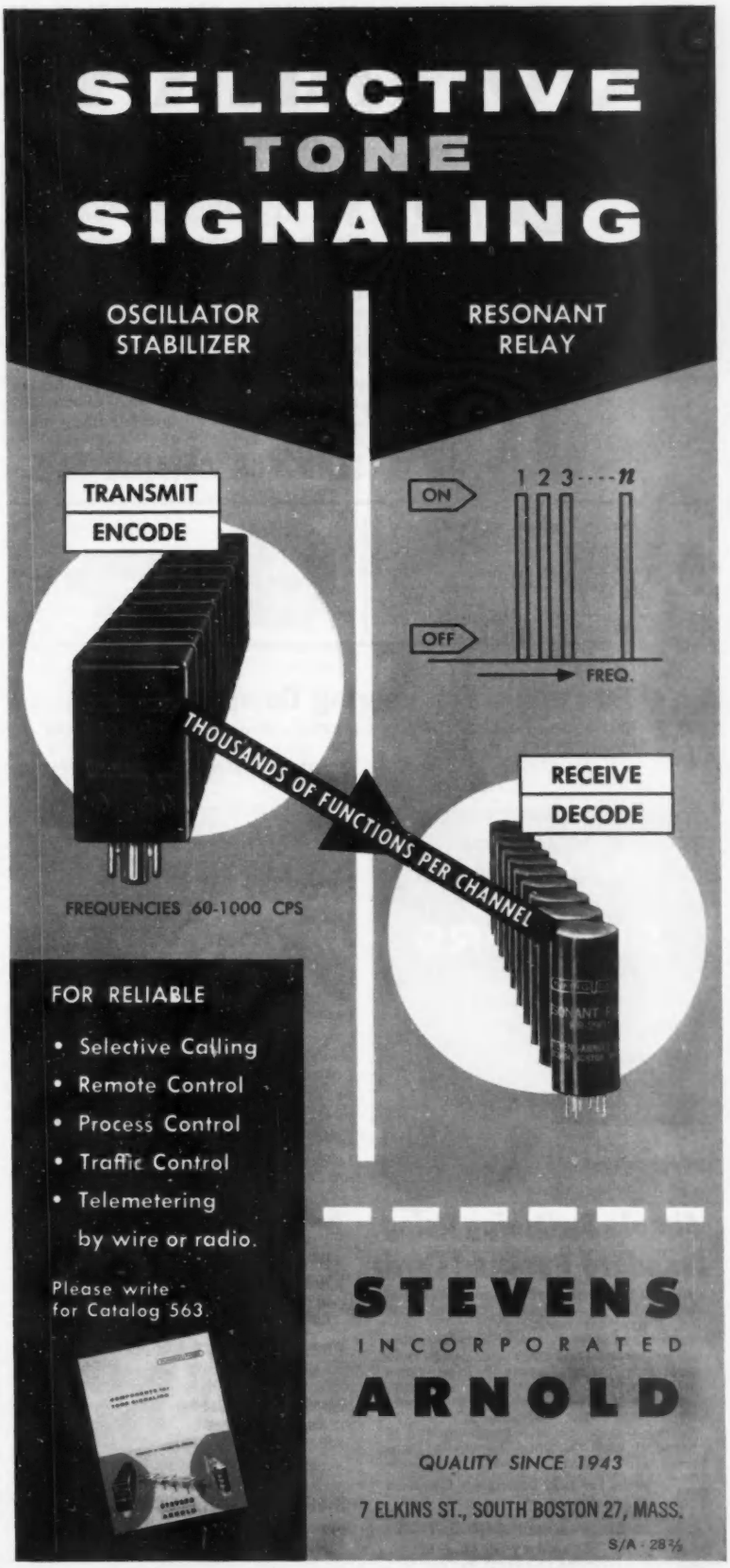
506—What You Should Know About Adaptive Systems, 17 pp. Is there such a thing as an adaptive control system? What approaches have been taken? What does the future hold? These are the questions the author answers in this three-article reprint, in sufficient detail and with sufficient references to provide a basic grounding in this latest area of control engineer interest. 50 cents.

505—The Basics of Optimum Response Relay Servos, 17 pp. Three part series summarizes all of the important design techniques that have been used to optimize the response of relay servos. The reprint describes the development of the optimum switching criteria, and outlines the progress that has been made in implementing this theory with hardware for second-order and higher-order systems. Extensive references provide a guide for further study. 50 cents.

504—System Characteristics of Modern Guidance Techniques, August 1960, 22 pp. In this special report five experts from three companies cover the system characteristics of inertial navigators, guidance radars, Doppler radar techniques, modern

(Continued on page 223)



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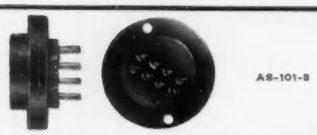

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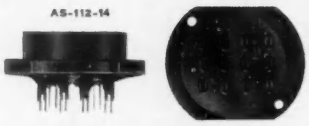

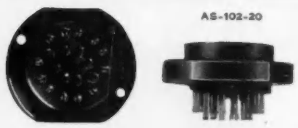

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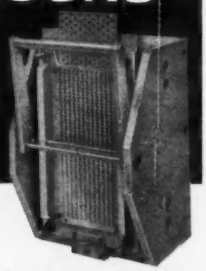

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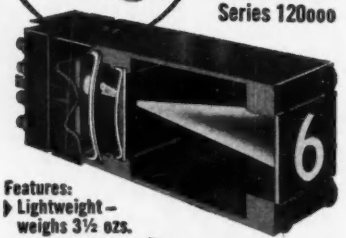

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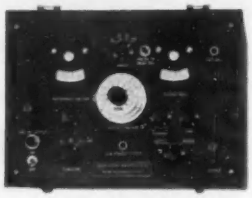

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(Continued on page 225)

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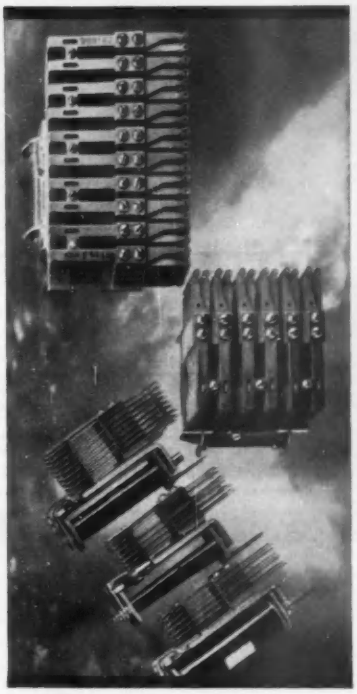

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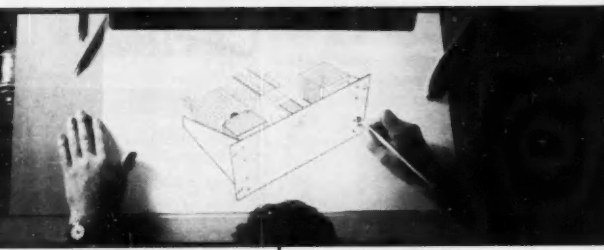

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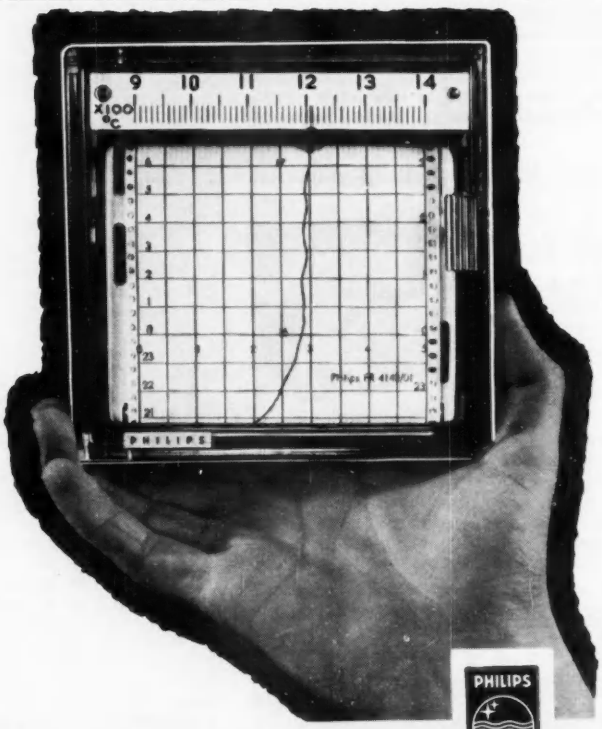

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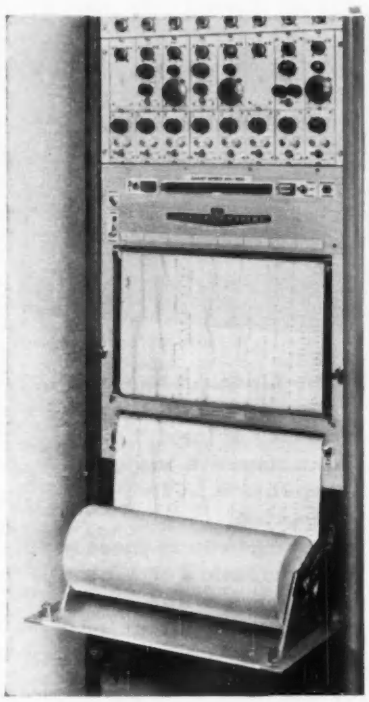

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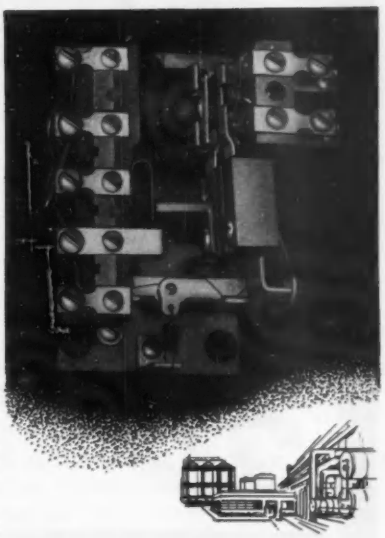

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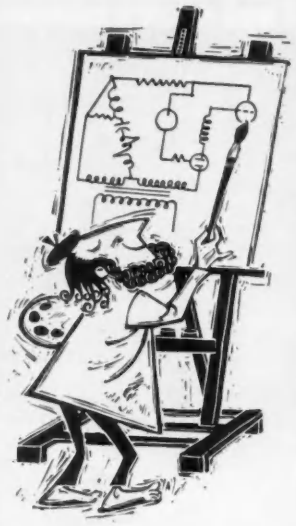

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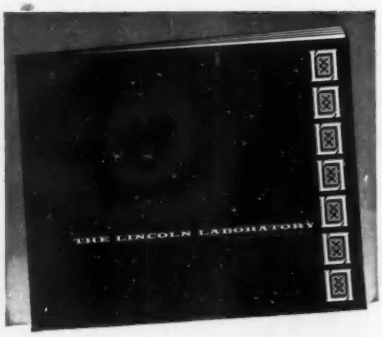

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REPRINTS cont'd

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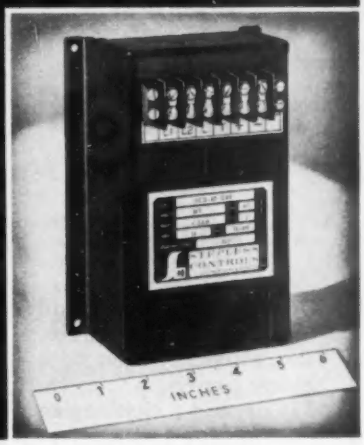

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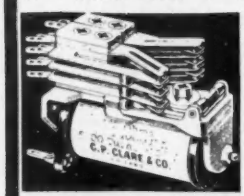

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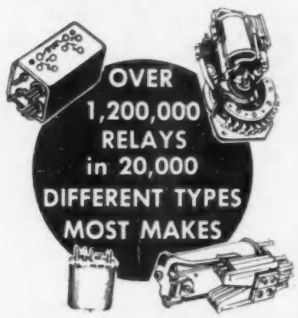

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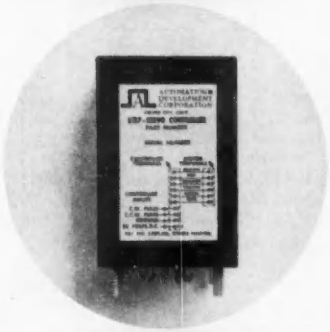

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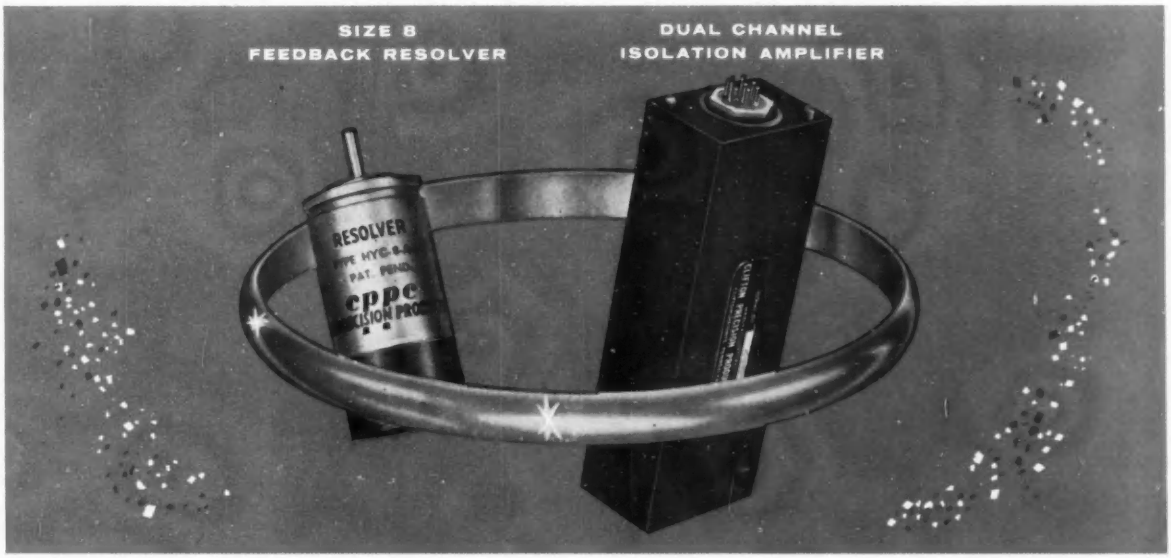

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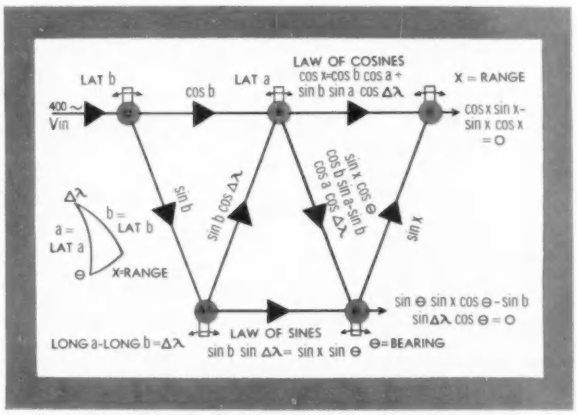
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LAT a
X = RANGE
400 ~ Vin
cos b
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sin b
sin b cos Δλ
cos b sin a - sin b cos a cos Δλ
sin x cos Θ
sin x
Δλ
a = LAT a
b = LAT b
Θ
X-RANGE
sin Θ sin x cos Θ - sin b sin Δλ cos Θ = 0
LONG a-LONG b = Δλ
LAW OF SINES
sin b sin Δλ = sin x sin Θ
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The essential data

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